May 1, 2018
1801.0114

Mr. John H. Ford
Director of Planning
HUMBOLDT COUNTY PLANNING & BUILDING DEPARTMENT
3015 H St.
Eureka, CA 95501

Subject: **Third-Party Geologic & Geotechnical Review**
Brown Quarry Expansion Plan
Humboldt County, California

Dear Mr. Ford:

Bajada Geosciences, Inc. (Bajada), is pleased to present this third-party review for the proposed R. Brown and Sons quarry expansion project, located near Willow Creek, Humboldt County, California. The following review presents our understanding of the project, our services performed, findings, and recommendations for this review based upon those findings.

INTRODUCTION

PROJECT UNDERSTANDING

Based on the County's description and documentation associated with this review, we understand that an expansion is proposed for the R. Brown and Sons Quarry from its existing 25-acre mining area to a total of 64-acre mining area. To facilitate the expansion, we understand that VESTRA Resources, Inc. (VESTRA), prepared a Mining and Reclamation Plan Amendment (Plan) to address various technical conditions associated with the project (VESTRA, 2016). That Plan included an Engineering Geological Evaluation (EGE) prepared by Trinity Valley Consulting Engineers, Inc. (TVCE), in conjunction with Lindberg Geologic Consulting (LGC).

During public review, we understand that comments were received asserting that the EGE had not adequately addressed slope stability and that the proposed quarry expansion plan could trigger slope failures that could block Highway 299 and Willow Creek (the drainage) leading to potential damage at Willow Creek (the community). A total of 12 contention points were raised by Busch Geotechnical Consultants (Busch) for which LGC provided responses. We understand that a second public comment period for a mitigated negative declaration for the project resulted in resubmittal of the comments noted above. We understand that in an effort to avoid preparation of an environmental impact report (EIR) for the project, the proponents and those providing comments agreed that a third-party review of the EGE would be performed to obtain an independent opinion regarding slope stability and its potential impacts to the project and surrounding areas, specifically traffic on Highway 299 and/or water quality and fisheries resources in Willow Creek. The County's scope associated with this third-party review posed two specific questions to be addressed. Those two questions are excerpted as follows:

> **Question 1:** … As the project is currently proposed and mitigated (during removal (mining), storage of materials, and reclamation), is there a potential for a slide (or slides) that could result in significant adverse environmental effects?
>
> Significant adverse environmental effects are defined as a slide (or slides) that could impede traffic on Highway 299 (either directly by a slide itself or through efforts to stabilize or mitigate such a slide) and/or result in transport of significant amounts of material to Willow Creek …
>
> **Question 2:** If the answer to Question 1 is "yes", then what mitigations (if any) are recommended to eliminate the potential for there to be a slide (or slides) that could impede traffic on Highway 299 (either directly by a slide itself or through efforts to stabilize or mitigate such a slide) and/or result in transport of significant amounts of material to Willow Creek?

This third-party review was performed to address those two questions.

SCOPE OF SERVICES

Services performed for this review are in general conformance with the proposed scope of services presented in our January 5, 2018 proposal. Our scope of services included:

- Attempted acquisition of existing information;
- Review of selected, available, relevant information;
- A site visit and reconnaissance of the site surface conditions at the quarry. That visit occurred on March 29, 2018;
- Sampling and unconfined compression testing of four rock samples obtained from the quarry site. Results of the laboratory testing are presented in Appendix A of this review;
- Evaluation of data collected during this review and data previously reported by others; and
- Preparation of this letter presenting the findings, conclusions, and recommendation of this review.

INFORMATION REVIEWED

Several reports, letters, and maps were reviewed as part of our scope and are cited in the References section of this review. Those documents include the proposed Plan prepared by VESTRA (2016), along with agency and private-sector responses to the Plan. The primary documents reviewed included:

- Engineering Geologic Evaluation for R. Brown and Sons Quarry (TVCE, 2015);
- Investigation of geology of the Brown Construction Company's Aggregate Quarry (Cooksley Geophysics, Inc. [CGI], 2004);
- Geotechnical Considerations Relevant to a Negative Declaration for the Brown Rock Quarry (Busch Geotechnical Consultants [Busch], 2016);
- Response to Comments, Brown's Rock Quarry (LGC, 2016);
- Geology of the Willow Creek 15' Quadrangle (Young, 1978); and
- Landslide Map of the Highway 299 Corridor (Falls & Hardin, 2005).

Additional documents and maps utilized during our review are cited within the References section of this review.

SITE CHARACTERIZATION

PREVIOUS WORK PERFORMED

TVCE (2015) characterized the quarry site as being underlain by undifferentiated surficial deposits, and rocks of the Galice Formation and Western Paleozoic and Triassic Belt. TVCE indicates that the undifferentiated surficial deposits were identified in areas where quarrying has yet to be performed. Based on Figure 5 of TVCE (2015), they mapped the Galice Formation within the western highwall, above the scale house, and the Western Paleozoic and Triassic Belt rocks within the eastern quarry area.

TVCE (2015) also refers to the quarry site being part of a relatively large Dormant-Young landslide complex mapped by Falls and Hardin (2005). They state that they observed "shallow surficial deposits containing materials, considered typical of landslide deposits, mantling fractured bedrock in cuts. These materials were clast-supported, with primarily-angular clasts that varied in size from gravel to boulders, and appeared to be deposited in a chaotic manner that lacked discernable bedding or other stratification."

TVCE (2015) and LGC did not perform any subsurface exploration at the quarry as part of their services. We inquired from Kevin Brown whether subsurface exploration had previously been performed at the quarry site to help assess resource volumes and found that no such work has previously been performed.

SITE OBSERVATIONS (BAJADA)

Our site observations were made to get a general understanding of what geologic and hydrogeologic conditions are exposed at the site. It was not within our scope nor our intention to geologically map and characterize the site in detail.

Our site observations of both the east and west quarry found that the majority of rock materials exposed within those slopes were relatively massive and structureless, with isolated boulders and rock outcrops exposed. The west quarry slope exhibited massive argillite that split into prismatic to blocky fragments and that exhibited highly deformed and contorted texture, where present. Blocks of metasedimentary rock materials (gravel to boulder-size) were present on the slope face and were derived from similar materials located upslope, above the argillite. No groundwater was observed discharging from the slope face.

The east quarry slope exposed clast-supported, relatively massive and structureless deposits of metasedimentary and ultramafic rock materials. These materials ranged in size from gravel to boulder with isolated outcrops present. Soil matrix was observed across most of the existing quarry face but the percentage of soil was not estimated or available for our review.

Locally exposed within the western quarry highwall are zones of massive greenish-grey to greenish-blue silty clay to clay (USCS symbols CL & CH) that we observed to be up to 12 feet wide along one bench (40.929783°, -123.676683°). These zones could be altered and highly weathered ultramafic rock materials or could be exposures of landslide planes.

Groundwater was observed discharging from the eastern highwall in a number of locations (40.92925°, -123.675633°; 40.930123°, -123.675906°). A moderate, steady flow of water (gallons per minute range) was observed but the flow rate not measured. In addition, groundwater could be heard flowing through the underlying gravelly rock materials at multiple locations across the slope face.

The area between the east and west quarry has limited geologic exposures along roadway cut slopes. Within those exposures, ultramafic rock materials were observed. Our observations of those materials are in general conformance with the mapped locations of serpentinite shown on Figure 2 of Cooksley (2004).

SUMMARY OF SITE CHARACTERIZATION EVALUATION

Based on our observations at the site, it is our opinion that intact bedrock is not exposed in the quarry highwalls. The lack of subsurface exploration to prove otherwise leaves no alternative but to assume that the quarry exposes translocated rock materials from the underlying landslide complex noted by TVCE (2015) and mapped by Falls and Hardin (2005). The quarry being located near the base of a landslide complex that is about 2,000 feet long and 1,750 feet wide, as shown on Plate 1 – Landslide

Complex (Falls and Hardin, 2005), would imply that the landslide materials underlying the quarry would be on the order of one hundred or more feet thick and not surficial deposits. The highly fractured rock exposed in the eastern and western quarry faces, including the relatively larger outcrops of what appears to be intact rock, appears to be derived from Galice Formation and Western Paleozoic and Triassic Belt rock materials that have been mobilized downslope by the landslides noted by Falls and Hardin (2005). It is our opinion that the relatively larger blocks of what appear to be intact bedrock are formational rock materials that have been rafted downslope within the landslide matrix forming a block-in-matrix (bimrock) condition.

Likely depths to groundwater beneath the quarry surface were not discussed within TVCE (2015) nor LGC (2016). Groundwater was observed discharging from the eastern quarry face at approximate elevation 1,885 above the larger landing within that area, as previously discussed.

STRENGTH PROPERTIES OF ON SITE ROCK MATERIALS

PREVIOUS WORK PERFORMED

TVCE (2015) did not perform any laboratory testing to evaluate the strength of the overall rock mass nor individual components of rock materials exposed within the quarry highwalls. Instead, rock strength properties were derived from a soil nail wall at what is referred to as the Enchilada Curve improvements located near Salyer in Trinity County (02-TRI-299-PM0.62), which is located about 5 miles east of the quarry. For that project, two rock strengths were identified based on rock description, as noted in the following table:

ENCHILADA CURVE ROCK STRENGTHS			
Rock Description	**Unit Weight (pcf)**	**Cohesion (psf)**	**Angle of Internal Friction (degrees)**
Decomposed Bedrock	135	300	35
Slate and Greywacke	155	2,000	40

The methods that Caltrans utilized to derive those strengths are not described (Caltrans, 2012).

STRENGTH ESTIMATES (BAJADA)

It was not within our scope nor our intention to rigorously evaluate the strength of massive rock materials nor the rock mass that is and will be exposed within the proposed quarry highwalls. Our scope did include evaluating whether rock mass strengths presented in TVCE (2015) appeared reasonable, which is what the following section describes.

While working for another company, Jim Bianchin (one of this review's authors) became involved with the Enchilada Curve project and observed site rock and discontinuity characteristics. The rocks exposed at that project site varied considerably from those exposed at the quarry site. At the Enchilada Curve site, thinly to thickly bedded intact Galice Formation consisting of phyllitic greywacke sandstone and slate were observed in areas where the relatively higher strength rock materials were encountered. In areas where decomposed bedrock was exposed at that project site, those rocks were generally gravel-sized angular rock fragments. Discontinuities were clearly exposed in the cut slope at Enchilada Curve across almost the entire soil nail wall face where slate and greywacke were mapped. The Enchilada Curve rock materials were intact and had not been sheared and translocated due to landsliding. Thus, the Enchilada Curve strength parameters, in our opinion, are not representative of the strength parameters for rocks exposed at the quarry site.

To estimate strength parameters more representative of rock materials exposed at the Brown Quarry, we utilized two methods:

- Unconfined compressive strengths of sampled rock materials were used to evaluate overall rock mass strength using Hoek-Brown failure criterion (Hoek et al., 2002); and
- Overall rock mass strengths were backcalculated from existing topographic conditions.

Those methods and their results are discussed further, below.

Unconfined Compression Test Results

Four rock samples were obtained at various locations within the existing quarry site, as noted on Plate 1. The samples were cored then tested to evaluate uniaxial compression strength, in accordance with standard test method ASTM D7012. The results of those tests are presented in Appendix A and described as follows:

UNCONFINED COMPRESSION TEST RESULTS

Sample	Compressive Strength (psi)
1	8,860
2	7,590
3	8,240
4	5,070

Hoek-Brown Failure Criterion Methods

For this method, rock mass strength parameters were derived using the Hoek-Brown failure criterion (Marinos et al., 2005; Marinos et al., 2000), using unconfined compression strength data noted above. The overall strength of a rock mass is difficult to estimate because of scale issues. Methods of estimating rock mass strength based on the strength of intact rock materials and the lithology, rock mass quality, and other factors are used to downgrade the measured intact rock strength to rock mass scale values. Once these strength properties have been estimated, they can be adjusted to account for the observed or expected level of construction disturbance. This method utilizes the Geological Strength Index (GSI), which was introduced to overcome issues with evaluation of rock mass strength for very poor-quality rock masses. The following table presents a summary of the rock mass strength parameters for the rock encountered within the quarry walls.

SUMMARY OF ROCK MASS STRENGTH PARAMETERS				
Basic Parameter	Symbol	Unit	Values	
			East Quarry	West Quarry
Unit Weight	Γ	pcf	150	135
Intact Uniaxial Compressive Strength (UCS)	σ_{ci}	psi	5,070	5,070
Geologic Strength Index	GSI	-	20	20
Petrographic Constant for Intact Rock	m_i	-	19	7
Partially Disturbed Rock Mass (Disturbance Factor D=0.7)				
Hoek-Brown Constant for Rock Mass	m_b	-	0.234	0.061
Hoek-Brown Constant	S	-	$9.2x10^{-6}$	$9.2x10^{-6}$
Friction Angle of Rock Mass	Ø’	degrees	15	10
Cohesion of Rock Mass	C’	ksi	0.095	0.061
Compressive Strength of Rock Mass	S_{cm}	ksi	0.009	0.009
Deformation Modulus	E_m	ksi	98.43	98.43

Using the values presented above and the software ROCKLAB! V1.031 (Rocscience, 2007), we estimated the rock mass strength based on the Hoek-Brown failure criterion (Hoek et al., 2002). Those criteria estimate the cohesion and angle of internal friction (Ø) based on the degree of weathering, fracturing, unconfined compressive strength, and rock type to evaluate what the overall strength of the rock mass might be. Based on those criteria, the following rock mass strength values were estimated.

Estimated Rock Strength		
Domain	**Cohesion (psf)**	**Ø**
Eastern Quarry	13,680	15°
Western Quarry	8,700	10°

Backcalculation of Rock Mass Strengths

We also performed stability analyses to estimate the rock mass strength for the quarry site. Stability analyses were performed by limit-equilibrium methods using SLIDE 7.0 (Rocscience, 2018b). To backcalculate those strengths, a cross section was prepared for the landslide complex under approximate existing topographic conditions. The location of that cross section (A-A') is shown on Plate 1. Slope stability analyses were then performed on that section and landslide strength values adjusted until a factor of safety (FOS) against slope failure of about 1.0 was obtained. In addition, relatively steeper portions of the landslide slopes were also evaluated in a similar manner to help estimate rock mass strength.

The area has been subjected to historical earthquakes since construction of the quarry and no reported slope failures or landslide reactivations have been reported at or above the quarry property. Thus, the evaluation of backcalculated rock mass strength should incorporate earthquake loading from the largest of those relatively recent earthquakes. To evaluate that loading, we searched the ShakeMap (USGS, 2018a) site to obtain peak ground accelerations from historical earthquakes occurring between 1990 and 2018. That search yielded a number of near- and far-field earthquakes that have affected Humboldt County. The earthquake generating the largest ground acceleration at the quarry during that search period was a magnitude M5.4 that occurred on April 29, 2008, about 10 miles southeast of Willow Creek. That earthquake generated a ground acceleration of 0.083g at Willow Creek. That acceleration was used within our evaluations.

Based on the results of our evaluations, we found the backcalculated rock mass strengths within the landslide materials exposed by the quarry to be as follows:

BACKCALCULATED ROCK MASS STRENGTH		
Material	**Cohesion (C, psf)**	**Angle of Internal Friction (Ø , degrees)**
Eastern Quarry Slope	13,650	20
Former Galice Fm. in Western Quarry Slope	8,700	16

Results of the backcalculations are presented in Appendix B – Slope Stability Evaluations. Aside from the Ø value for the Galice Formation in the Western Quarry, the backcalculated strengths conform closely with the strength values obtained using the Hoek Brown failure criterions (2002).

SUMMARY OF ROCK STRENGTH EVALUATION

Methods to evaluate the strengths of on-site rock materials were not performed by TVCE (2015); rather, they relied on existing rock strength values obtained from the Enchilada Cure project located approximately 5 miles east of the Brown Quarry.

Based on our experience at the Enchilada Curve project, it is our opinion that rock materials from the Enchilada Curve were of greater relative quality and were somewhat stronger. Rock mass strengths for landslide deposits at the Brown Quarry, estimated as discussed above, are stronger at relatively shallower depths but weaker when overburden pressures increase.

Comparing the static Factors of Safety for Section A-A' using the TVCE (2015) Enchilada Curve strengths (C=2,000 psf, Ø=20°) and the BAJADA backcalculated strengths noted above (C=13,650 psf, Ø=15°) results in a FOS that is 34% greater for the Enchilada Curve strengths than for the backcalculated strengths. Based on this finding, BAJADA elected to use the backcalculated strengths described above for the remaining stability analyses in this study.

SLOPE STABILITY

PREVIOUS WORK PERFORMED

To evaluate stability of various possible quarry highwall inclinations, TVCE (2015) performed stability analyses utilizing limit-equilibrium methods and through kinematic evaluations of rock wedge and planar failures along discontinuity surfaces identified at the site. These individual methods are discussed in separate sections, below.

As discussed within TVCE (2015), commonly accepted FOS values of 1.5 and 1.1 for static and pseudostatic conditions, respectively, are typically utilized for most engineered slope design. For quarries, however, we agree with TVCE that a static FOS of 1.25 and a pseudostatic FOS of greater than 1.0 are typically acceptable. Those lower FOS values are what are utilized within this review as threshold values.

Kinematic Evaluations

TVCE (2015) collected 133 rock discontinuity orientations from the quarry site and evaluated those data using Markland's kinematic test to estimate the potential presence of rock planar and wedge failures. Those data were input into DIPS 6.0 assuming only one structural domain was present at the site. Contouring of the discontinuity poles identified a total of 5 predominant discontinuity groupings. Kinematic evaluations for the east and west quarry faces were performed using the approximate proposed slope orientation and inclination, and a Ø of 35 degrees. A similar evaluation was performed for potential wedge failures between intersecting primary discontinuity groupings identified from their evaluation. TVCE (2015) found only minor opportunity for potential planar failure within their Discontinuity Group 2 and no potential wedge failures. On this basis, TVCE (2015) performed no further limit-equilibrium analyses for rock discontinuity stability evaluations.

Limit-Equilibrium Analyses

TVCE (2015) utilized rock strengths derived from the Enchilada Curve project (as discussed above) in conjunction with possible highwall slopes inclined at 0.5:1 (horizontal:vertical), 1:1, and 1.5:1 to estimate the maximum stable slope inclination that could be utilized for the project. They evaluated phreatic surfaces occurring at the base, at a height of about 20%, and at the ground surface of the possible highwalls. Those phreatic surfaces at the base and at a height of 20% of the cut slope were projected into the highwall as a flat surface. For each highwall inclination scenario, the top of the slope was modeled as a flat plane with no inclined slope ascending away from the top of the proposed highwall. Slope stability evaluations were performed using Spencer's method. Static and pseudostatic evaluations were performed with the pseudostatic models using a horizontal ground acceleration of 0.15g.

Based on the results of their stability analyses, TVCE (2015) found the following:

- Slopes modeled with the decomposed bedrock strength of C=300 psf and Ø=35°, had FOS values below threshold values for all 0.5:1 and 1:1 highwall scenarios, and for the fully saturated 1.5:1 cut slope;
- Slopes modeled with the Slate/Greywacke strength of C=2,000 psf and Ø=40° were found to meet threshold values for all highwall inclinations evaluated except for 0.5:1 where the slope is fully saturated.

Based on the results of their evaluations, TVCE (2015) recommended that the new highwall be constructed up to an inclination of 1:1. Plans provided by VESTRA (2016) show that the proposed new quarry slopes are inclined at up to 1:1 with 20-foot wide benches, resulting in an overall quarry inclination of about 40 degrees (1.19:1).

STABILITY ANALYSES (BAJADA)

Kinematic Evaluations

BAJADA evaluated the TVCE (2015) data to identify the potential for more than one structural domain at the quarry site and to check the results of the kinematic analyses performed by TVCE (2015).

To evaluate the potential for more than one structural domain in the project area, discontinuity orientations reported by TVCE (2015) for the eastern quarry face, western quarry face, and that area between the quarry faces were plotted separately on stereonets and the poles contoured. Those plots are presented in Plate 2 – Structural Domain Evaluation. The contoured poles indicate structural differences between the three areas, some of which might be due to insufficient numbers of poles available for the analyses; however, distinct pole concentration differences are present between the areas indicating that the east, west, and middle areas have unique structural characteristics and could perform differently from a stability perspective.

Two predominant pole groupings are present within each of the structural domains. Those groupings are oriented as follows:

- 60 degrees east of north and dipping at about 70 degrees north (TVCE Group 1); and
- 80 degrees east of north and dipping at about 50 degrees north (TVCE Group 2).

Dip directions for those groupings correspond to the general direction of movement of the landslide complex underlying the quarry site and are likely associated with tensional deformation of rock materials created by past (pre-quarry – possibly prehistoric) movement of the slope. The remainder of the discontinuity groupings from each structural domain do not conform to regional bedding or fault orientations reported by Young (1978) and are relatively diverse implying possible independent rotation due to slope movement.

To help evaluate the TVCE (2015) discontinuity data, we visited the quarry site and measured discontinuity orientation data at some of the outcrops mapped by TVCE. This was not intended to be an exhaustive confirmation of their measurements but a spot-check to generally confirm what had been reported. As such, a total of 30 discontinuity orientations were recorded and compared to TVCE data. Our measurements were in close agreement with the reported data and, therefore, support TVCE's work. In addition, our evaluation of TVCE data, regardless of the structural domain variances, generally confirms their findings regarding the potential for planar and wedge failures.

Limit-Equilibrium Analyses

We utilized SLIDE 7.0 (Rocscience, 2018b) to perform limit-equilibrium slope stability evaluations for this review. Our evaluations during this portion of the study consisted of the following:

- Replication of slope stability models presented by TVCE (2015) to confirm their results (digital files of those models were requested from LGC but were not available);
- Preparation of three new cross sections (B-B', C-C' and D-D'), as noted on Plate 1; and
- Performance of stability analyses on those three new sections for existing conditions and proposed quarry highwall inclinations.

Digital files of the slope stability evaluations presented by TVCE (2015) were not available for this study; therefore, BAJADA reconstructed those models and evaluated them using the same criteria and methods applied by TVCE. In each instance, our FOS values were identical or within 0.1% of the TVCE (2015) reported values, thus confirming their reported analyses.

Additionally, the TVCE (2015) slope stability models did not include ascending slopes above proposed highwall cut slopes. Accordingly, BAJADA constructed three new cross sections (B-B', C-C' and D-D') extending across the quarry areas and slopes above the highwalls. Topographic information for these cross sections was obtained from VESTRA (2016) and Falls and Hardin (2005). The locations of the cross sections are shown on Plate 1. For each cross section, we performed the following limit-equilibrium slope stability analyses:

- Static evaluations using the backcalculated rock mass strengths previously discussed, on existing topographic conditions, and with groundwater conditions projected from site observations;
- Static and pseudostatic evaluations of proposed highwall geometry utilizing previously discussed backcalculated rock mass strengths and with groundwater conditions projected from site observations; and
- Static and pseudostatic evaluations of proposed highwall geometry utilizing strength values from the Enchilada Curve project (same as used by TVCE) and with groundwater conditions projected from site observations.

In addition, we utilized a pseudostatic horizontal earthquake loading value of 0.17g versus the 0.15g utilized by TVCE (2015). We derived that value by taking the probabilistically-estimated ground acceleration of 0.41g for a 475-year return period (10% probability of exposure within a 50-year time period; USGS 2018b) and reducing that value in accordance with methods described by CGS (2008) and Blake et al. (2002), which are the state of the practice methods utilized within most California agencies.

The following table presents a summary of the results of those analyses. Graphical results of our stability analyses are presented in Appendix B.

RESULTS OF STABILITY ANALYSES				
Cross Section	Slope Condition Evaluated	Strength Values Used[1]	Factor of Safety[2]	Acceptable? [2]
B-B'	Existing Topography, Static	Backcalculated	1.25	Y
B-B'	Proposed 1:1 Highwall, Static	Backcalculated	1.23	N
B-B'	Proposed 1:1 Highwall, Pseudostatic	Backcalculated	0.87	N
B-B'	Proposed 1:1 Highwall, Static	TVCE (2015)	1.65	Y
B-B'	Proposed 1:1 Highwall, Pseudostatic	TVCE (2015)	1.16	Y
C-C'	Existing Topography, Static	Backcalculated	1.26	Y
C-C'	Proposed 1:1 Highwall, Static	Backcalculated	1.13	N
C-C'	Proposed 1:1 Highwall, Pseudostatic	Backcalculated	0.87	N
C-C'	Proposed 1:1 Highwall, Static	TVCE (2015)	1.07	N
C-C'	Proposed 1:1 Highwall, Pseudostatic	TVCE (2015)	0.82	N
D-D'	Existing Topography, Static	Backcalculated	1.25	Y
D-D'	Proposed 1:1 Highwall, Static	Backcalculated	1.23	N
D-D'	Proposed 1:1 Highwall, Pseudostatic	Backcalculated	0.89	N
D-D'	Proposed 1:1 Highwall, Static	TVCE (2015)	1.24	N
D-D'	Proposed 1:1 Highwall, Pseudostatic	TVCE (2015)	0.96	N

[1] – Backcalculated: C=13,650 psf, Ø= 20°; TVCE (2015): C=2,000 psf, Ø= 40°.
[2] – FOS thresholds for this study: static = 1.25 & pseudostatic = >1.

SUMMARY OF SLOPE STABILITY EVALUATION

It is our opinion that the kinematic evaluations for rock slope stability for the quarry site were performed by TVCE (2015) in accordance with generally accepted practices and that the results of those analyses are reasonable. It is also our opinion that the stability of the overall quarry slope will not be governed by rock wedge or planar failures. We anticipate that the proposed highwalls will expose predominantly structureless rock materials that have been chaotically fractured by landsliding disrupted by isolated exposures of relatively competent rock materials that have been rafted into place (bimrock). Thus, potential rock planar and wedge failures will likely have only limited influence on worker safety and local slope stability, similar to what is currently observable at the site.

Based on our evaluations of limit-equilibrium modeling of slope stability by TVCE (2015), we find that their evaluations overestimated the stability of proposed quarry highwalls due to the following reasons:

- TVCE (2015) slope stability models did not consider the ascending slope above the proposed quarry highwall;
- Strengths utilized within their model were likely overestimated for the Section B-B' highwall analyses performed by BAJADA;

- Groundwater was modeled as a relatively flat and simplistic surface, which likely is not present in nature. This was not assessed by TVCE; however, groundwater was observed discharging from the existing quarry face at numerous locations during our site observations; and,
- The horizontal ground motions utilized in their analyses were slightly underestimated.

Based on our limit-equilibrium slope stability evaluations, the existing quarry highwalls meet acceptable static FOS thresholds using the backcalculated strength values. The stability analysis results using rock mass strengths developed by BAJADA and the strengths developed by TCVE (2015) from the Enchilada Curve project, yielded similar results, except for the Section B – B' analyses. The analyses for Sections C-C' and D-D' resulted in both static and pseudostatic FOS values below acceptable thresholds when utilizing either the TVCE (2015) strength values or the BAJADA strength values developed for this study.

DISCUSSION

As noted in the Project Understanding section of this review, two questions were posed by the County to be addressed. Answers to those questions are presented below.

Question 1 – Potential for Slide to Pose Significant Adverse Environmental Effects?
Based on our review, we find that evaluations performed by TVCE (2015) overestimate stability of the proposed highwall geometries at the site. Our evaluations found that the proposed 1:1 cut slope with 20-foot wide benches does not meet currently accepted thresholds for static and pseudostatic slope stability, even when using strength values utilized by TVCE (2015). This does not mean that the slopes will fail under static conditions if constructed as proposed; however, there is increased risk of significant slope failure if the slopes are constructed as proposed versus having a static FOS that meets acceptable thresholds. Conversely, the pseudostatic FOS was found to be below 1.0, indicating that the slope would likely fail under earthquake forces from a large, near-field earthquake.

Based on the size and height of the proposed quarry slope and landslide deposits upslope from the quarry, a catastrophic slope failure that would extend across Highway 299 cannot be precluded using the information available at the time of this review. The 10 most critical failure planes identified by our slope stability evaluations for Sections B-B' and D-D' extend across Highway 299. The 10 most critical failure planes identified for our Section C-C' do not extend across the highway but mobilize a large volume of landslide deposits that may not be contained by the landing at the base of slope, thus, spilling over onto Highway 299.

Based on the information available to us during this review, it is our opinion that there is a potential for a slide that could result in significant adverse environmental effects for this project.

It should be noted that TVCE could perform additional work to further constrain rock mass strengths and groundwater elevations to refute this opinion. Our work did not include a scope to rigorously evaluate rock mass strength, to constrain subsurface conditions, or to model (e.g., by finite-element, finite-difference or three-dimensional methods) landslide run-out or permanent slope displacement during seismic events. Such additional work, if performed according to generally accepted methods, could show that slope stability conditions are more favorable than data available at the time of this review indicate.

Question 2 – Possible Mitigations to Eliminate Significant Adverse Environmental Effects?
For a quarry this size with spatial constraints due to property lines and Highway 299, there are few mitigations available to reduce the risk of significant environmental effects due to slope instability. The only relatively cost-effective method that we can identify at this time would be to flatten the proposed quarry slope to increase the gross stability of the highwall under static and pseudostatic conditions. However, this would result in a smaller resource available to the operator and a shorter quarry life than anticipated.

Based on our preliminary evaluation for Section C-C', which appears to be the most critical cross section evaluated during this review, flattening the slope to 34 degrees (1.5:1) and lowering the phreatic surface behind the highwall could increase the FOS under static and pseudostatic conditions to more than 1.25 and 1.0, respectively. The lowering of the phreatic surface would have to be permanent and would involve installation of multiple arrays of very long horizontal drains that would need to be maintained into perpetuity. This is conceptual and should be verified through rigorous design-level geotechnical studies performed by the project geotechnical engineer.

RECOMMENDATIONS

We recommend that more rigorous evaluations of project site conditions be performed to constrain the following:

- <u>Subsurface rock conditions</u> - Sufficient coring should be performed to characterize the distribution of rock materials, locations and depths of potential landslide planes, rock quality designations (RQD), fracture density, rock mass rating (RMR), and variation of rock quality with depth. Geophysical surveys could assist in this process but should not replace invasive subsurface exploration;
- <u>Piezometric surfaces</u> - Groundwater depths should be evaluated through at least one, if not several, seasons to estimate the highest piezometric surface to be used for stability evaluations;
- <u>Rock mass strengths</u> - Representative samples should be tested to evaluate the gross strength of rock materials that will be exposed within the slopes. This could include in-situ testing using pressuremeters or on-site, large-scale direct shear tests. Rock mass strength estimates should then be made to estimate the gross strength of the slope so that more refined stability

analyses can be performed. The rock mass strength can be estimated from a variety of methods including Hoek Brown (2002), Bieniawski (1989), Medley (2001), Linquist & Goodman (1994), etc.

Information collected from additional studies should be used to perform additional slope stability analyses to help constrain the maximum slope that can be constructed for the quarry site and not result in significant, adverse, environmental effects due to slope instability.

CLOSURE

We appreciate the opportunity to provide our services for this review. If you have questions regarding this information presented herein, please contact us at your earliest convenience.

Regards,

BAJADA GEOSCIENCES, INC.

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Principal Engineering Geologist

Jon Everett, P.E., G.E.
Principal Geotechnical Engineer

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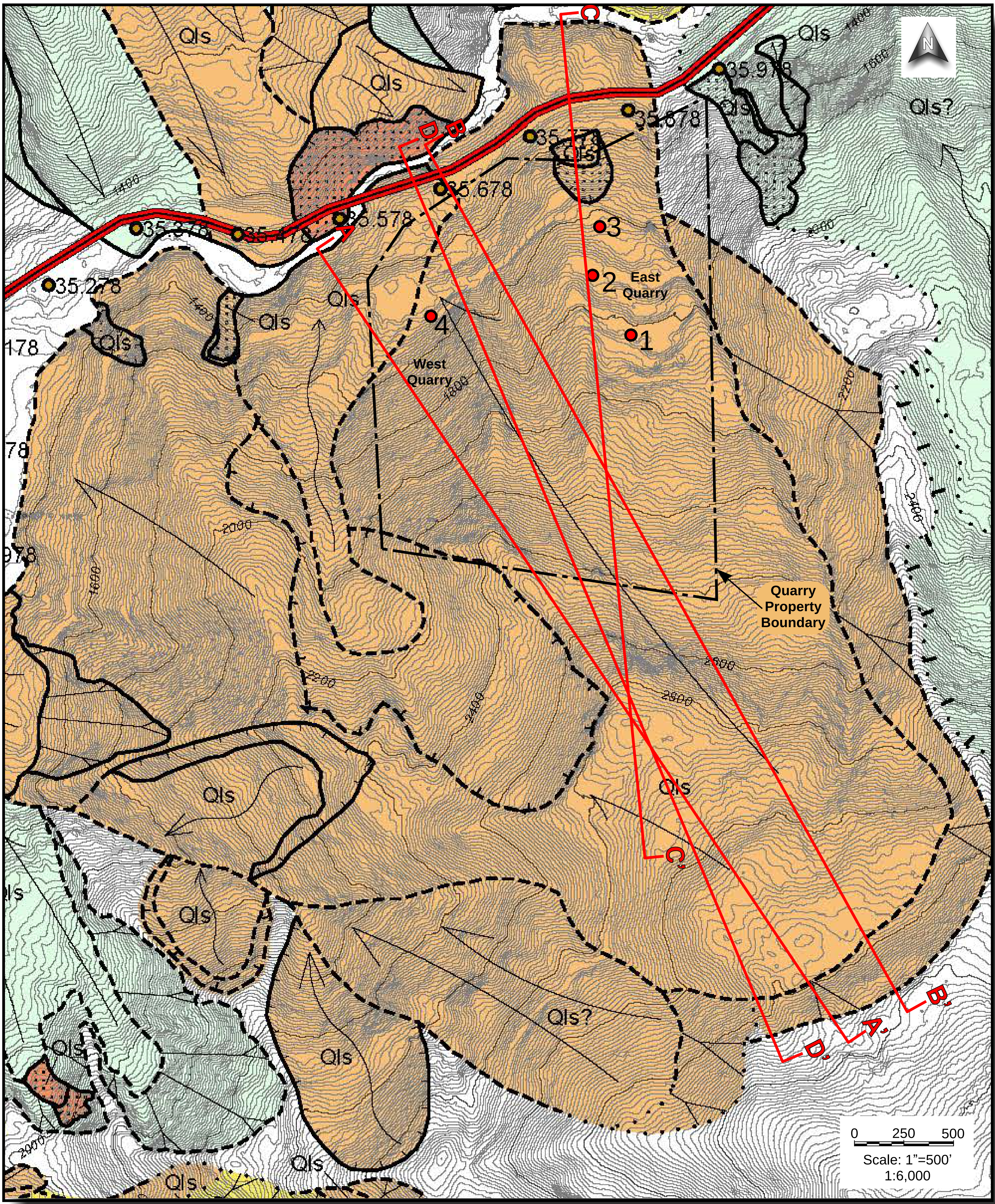


ACTIVE or HISTORIC: The landslide appears to be currently moving or movements have been recorded in the past. Fresh cracks, disrupted vegetation or displaced or damaged cultural features indicate recent activity. Water may pond in depressions created by rotation of the slide mass or blockage of stream drainage.

DORMANT-YOUNG: The landforms related to the landslide are relatively fresh, but there is no record of historic movement. Cracks in the slide mass are generally absent or greatly eroded; scarps may be prominent but are slightly rounded. Depressions or ponds may be partly filled in with sediment, but still show phreatophytic vegetation.

DORMANT-MATURE: The landforms related to the landslide have been smoothed by erosion and re-vegetated. The main scarp is rounded, the toe area has been eroded and some new drainages established within the slide area. Benches and hummocky topography on the slopes are subdued and commonly obscured by dense, relatively uniform vegetation.

DORMANT-OLD The landforms related to the landslide have been greatly eroded, including significant gullies or canyons cut into the landslide mass by small streams. Original headscarp, benches and hummocky topography are now mostly rounded and subtle. Closed depressions or ponds now breached or filled in. Vegetation has recovered and mostly matches the vegetation outside the slide boundaries.

Jg — Galice Formation (Jurassic) - Very fine- to coarse-grained gray phyllitic metagraywacke. Finer portions altered to slate and phyllitic slate. Level of metamorphism generally increases westward through the unit. Numerous exposures streams show graded bedding typical of turbidite sequences. Intruded by scattered metamorphic-felsite dikes and sills. Areas underlain by slates and phyllitic slate are especially subject to slope failure.

Jr — Rogue (?) Formation (Jurassic) - Mafic (high in magnesium and iron) to intermediate volcanic flows and tuffs, now altered to greenstone. Some volcanic conglomerates in the upper portion of the unit. Stringers and layers of chert or siliceous argillite to 1 inch thick are present sporadically.

gn — Friday Camp gneiss (Jurassic?) - Weakly foliated hornblende-diorite gneiss. Alternatively, unit may be related to an ophiolite sequence and gneiss appearance may be due to cumulate layering in gabbro within the sequence. May also be altered Rogue Formation.

ŦPz — Western Paleozoic and Triassic belt mélange (Triassic) - Fine-grained volcanic rocks, fine- to medium-grained greywacke, chert and siliceous argillite, lenses of serpentinite, local limestone and conglomerate and small intrusive igneous bodies. Individual rock units are discontinuous and overall rock character is highly fractured and chaotic.

ps — Undifferentiated Ultramafic rocks (Mesozoic) - Seen as sporadic sheared lenses and sheet-like masses of peridotite and serpentinite. Larger bodies are serpentinized peridotite, while smaller bodies are largely serpentinite. No occurrences of asbestos have been noted in this unit.

ROCK SLIDE: Slope movement with bedrock as its primary source material. This class of failure includes rotational and translational landslides; relatively cohesive slide masses with failure planes that are deep-seated in comparison to those debris slides of similar areal extent. The slide plane is curved in a rotational slide. Movement along a planer joint or bedding surface may be referred to as translational. Complex versions with combinations of rotational heads and translational movement or earthflows downslope are common. Landslide boundary indicates confidence; solid line- definite, dashed line - probable, dotted line - questionable. indicates a scarp, arrows show direction of movement. Qls denotes deposit when present.

EARTHFLOW: Slow to rapid movement of mostly fine-grained soil with some rocky debris in a semi-viscous, highly plastic state. After initial failure, the mass may flow or creep seasonally in response to changes in groundwater level. These types of slope failures often include complexes of nested rotational slides and deeply incised gullies. Landslide boundary indicates confidence; solid line- definite, dashed line - probable, dotted line - questionable. indicates scarp, arrows show direction of movement. Qls denotes deposit when present.

DEBRIS SLIDE: Mass of unconsolidated rock, colluvium, and coarse-grained soil that has moved slowly to rapidly downslope along a relatively steep, shallow, translational failure plane. Debris slides form steep, unvegetated scars in the head region and possibly irregular, hummocky deposits in the toe region. Scars commonly erode and remain unvegetated for several seasons depending on slope aspect. Landslide boundary indicates confidence; solid line- definite, dashed line - probable, dotted line - questionable. Landslide deposit is locally absent. indicates scarp, no arrows are used to portray landslide movement direction. Qls denotes deposit when present.

DEBRIS FLOW: Long stretches of bare ground that have been scoured and eroded to bedrock by extremely rapid movement of water-laden debris. Debris flows are commonly triggered by debris sliding in the source area during high intensity rains. Debris is often deposited downslope as a tangled mass of organic material in a matrix of rock, and soil; debris may be reworked and incorporated into subsequent events; lack of vegetation indicates recent activity. Landslide boundary indicates confidence; solid line- definite, dashed line - probable, dotted line - questionable. Landslide deposit is locally absent. indicates scarp, arrow shows direction of movement. Qls denotes deposit when present.

Approximate Quarry Property Line

D D' Cross Section Used For Stability Analyses

1 Rock Sample Location

Basemap from Falls & Hardin (2005)

LANDSLIDE COMPLEX

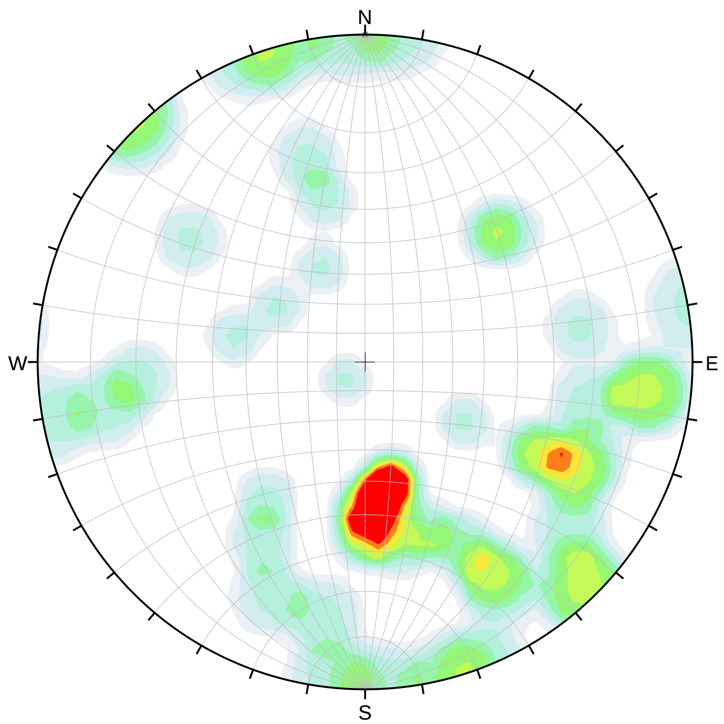
Third-Party Review
R. Brown & Sons Quarry
Willow Creek Vicinity
Humboldt County, California

Plate No. 1

BAJADA Geosciences, Inc.

Project no. 1801.0114

West Quarry Discontinuity Density

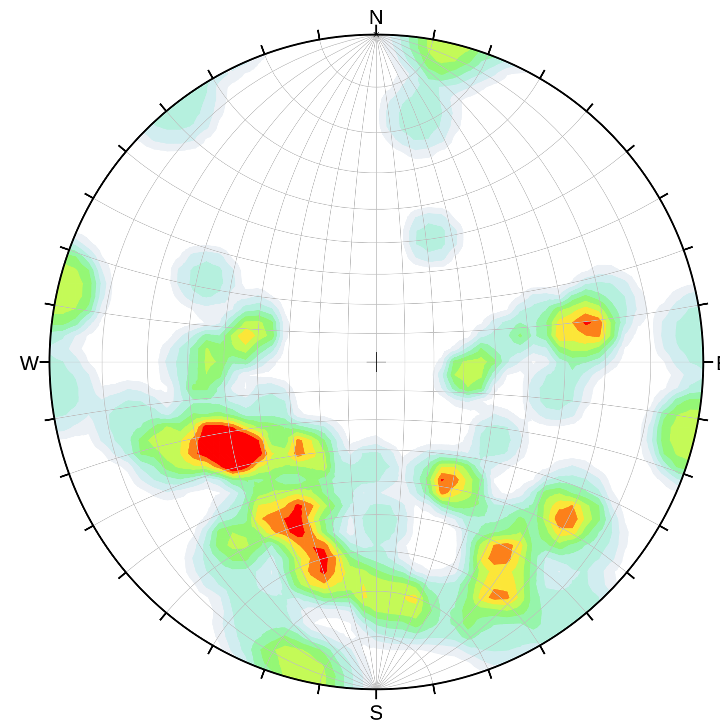


Color	Density Concentrations
	0.00 - 0.70
	0.70 - 1.40
	1.40 - 2.10
	2.10 - 2.80
	2.80 - 3.50
	3.50 - 4.20
	4.20 - 4.90
	4.90 - 5.60
	5.60 - 6.30
	6.30 <

Contour Data	Pole Vectors
Maximum Density	10.96%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Plot Mode	Pole Vectors
Vector Count	45 (45 Entries)
Hemisphere	Lower
Projection	Equal Angle

East Quarry Discontinuity Density

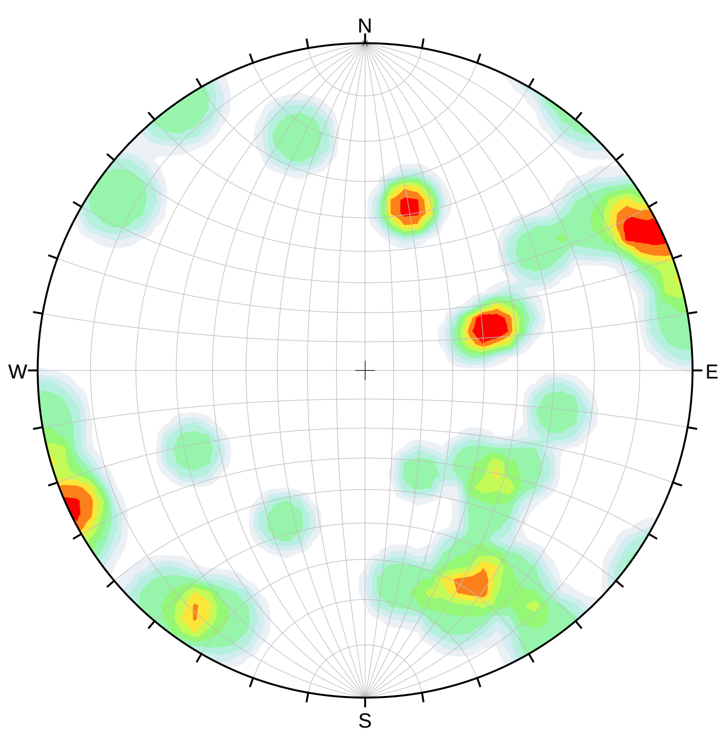


Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	6.28%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Plot Mode	Pole Vectors
Vector Count	59 (59 Entries)
Hemisphere	Lower
Projection	Equal Angle

Middle Area Discontinuity Density

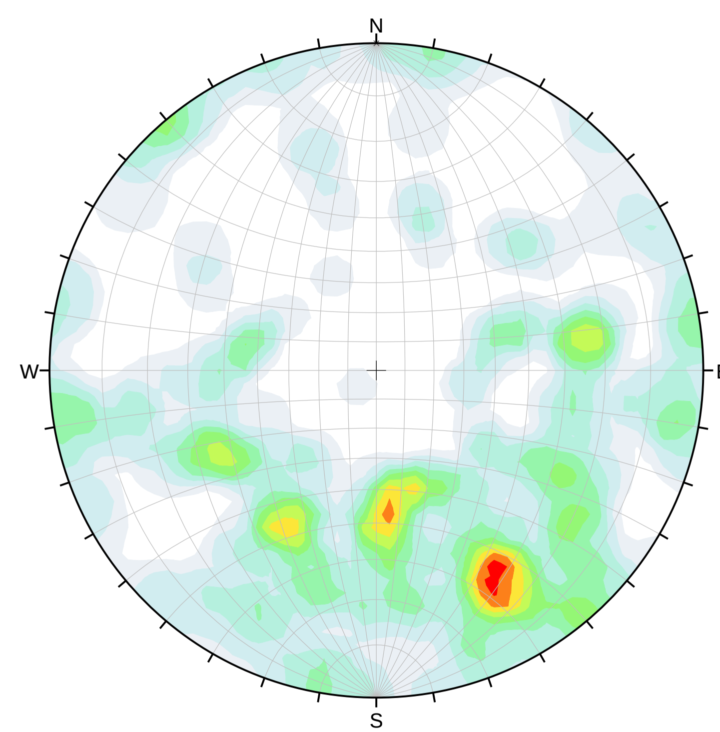


Color	Density Concentrations
	0.00 - 0.80
	0.80 - 1.60
	1.60 - 2.40
	2.40 - 3.20
	3.20 - 4.00
	4.00 - 4.80
	4.80 - 5.60
	5.60 - 6.40
	6.40 - 7.20
	7.20 <

Contour Data	Pole Vectors
Maximum Density	8.56%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Plot Mode	Pole Vectors
Vector Count	26 (26 Entries)
Hemisphere	Lower
Projection	Equal Angle

All Areas Discontinuity Density



Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 <

Contour Data	Pole Vectors
Maximum Density	4.96%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Plot Mode	Pole Vectors
Vector Count	133 (133 Entries)
Hemisphere	Lower
Projection	Equal Angle

Discontinuity data from TVCE (2015)

STRUCTURAL DOMAIN EVALUATION

Third-Party Review R. Brown & Sons Quarry Willow Creek Vicinity Humboldt County, California	Plate No. 2
BAJADA Geosciences, Inc.	Project no. 1801.0114

APPENDIX A

Laboratory Test Results

APPENDIX B
LABORATORY TESTING

Laboratory Analyses
Laboratory tests were performed on selected bulk soil samples to estimate engineering characteristics of the various earth materials encountered. Testing was performed under procedures described in one of the following references:

- ASTM Standards for Soil Testing, latest revision;
- Lambe, T. William, Soil Testing for Engineers, Wiley, New York, 1951;
- Laboratory Soils Testing, U.S. Army, Office of the Chief of Engineers, Engineering Manual No. 1110-2-1906, November 30, 1970.

Unaxial Unconfined Compression Strength
Four rock samples were tested to evaluate uniaxial unconfined compressive strengths of those samples. Testing was performed in accordance with standard test method ASTM D7012 Method C. Results of the tests are presented in the attached page labeled *Rock Core Compressive Strength Data*.

M T I
Materials Testing, Inc.

8798 Airport Road
Redding, California 96002
(530) 222-1116, fax 222-1611

865 Cotting Lane, Suite A
Vacaville, California 95688
(707) 447-4025, fax 447-4143

Client: BAJADA Geosciences, Inc.
28301 Inwood Road
Shingletown, CA 96088

Date: 04/03/18
Client No: 3237-005
Report No: 0100-001

Project: Brown Quarry Rock Core
Source: Brown Quarry

ROCK CORE COMPRESSIVE STRENGTH DATA
(ASTM D7012 Method C)

Identification	Rock 1	Rock 2	Rock 3	Rock 4
Date Cored	03/31/18	03/31/18	03/31/18	03/31/18
End Preparation Date:	03/31/18	03/31/18	03/31/18	03/31/18
Date Tested	03/31/18	03/31/18	03/31/18	03/31/18
Average Diameter, in	1.98	1.97	1.97	1.98
Average X-Sect. Area, in^2	3.08	3.05	3.05	3.08
As Received Length, in	5.82	7.20	5.41	7.70
Trimmed Length, in	3.96	3.94	3.94	3.96
L/D Factor	2.0	2.0	2.0	2.0
Maximum Load, lbs.	27,280	23,160	25,120	15,620
Compr. Strength, psi	**8,860**	**7,590**	**8,240**	**5,070**
Fracture Pattern, Type	Cone and Vertical Cracking	Cone Cracking	Cone and Vertical Cracking	Columnar Vertical Cracking

Notes: Specimens prepared in accordance with ASTM D4543.

APPENDIX B
Slope Stability Analyses

APPENDIX B
SLOPE STABILITY ANALYSES

METHODS OF ANALYSIS

Computer-aided slope stability analyses were performed using the computer program SLIDE 7.0. SLIDE 7.0 was developed by Rocscience, Inc. (2018) and offers a wide variety of limit-equilibrium procedures. Those include the Modified Bishop, the Simplified and Corrected Janbu, Corps of Engineers #1 and #2, GLE/Morgenstern-Price, Lowe-Karafiath, and the Spencer methods. Those limit-equilibrium procedures are all "method of slices", but they differ from the Ordinary Method of Slices (Fellenius method – also included within SLIDE 7.0) in:

1. The simplifying assumptions that have been made achieve static determinacy; and
2. The particular conditions of equilibrium that are satisfied.

SLIDE 7.0 allows the use of any or all of the methods listed above because they better satisfy limit equilibrium conditions. A summary of the equilibrium conditions satisfied by each of these procedures and the type of failure surface for which each is useful is presented in the following table.

EQUILIBRIUM CONDITIONS SATISFIED BY PROCEDURES

Procedure of Analysis	Overall			Individual Slices			
	Moment	Vertical Force	Horizontal Force	Moment	Vertical Force	Horizontal Force	Slip Surface
Ordinary Method of Slices (Fellenius)	Yes	No	No	No	No	No	Circular Arc
Modified Bishop	Yes	(Yes)[1]	No	No	Yes	No	General Shape[2]
Simplified Janbu	No	(Yes)[1]	(Yes)[1]	No	Yes	Yes	General Shape
Spencer	Yes	(Yes)[1]	(Yes)[1]	Yes	Yes	Yes	General Shape

Per Wright (1969); (Yes)[1] - Parentheses indicate that this condition of equilibrium is implicitly satisfied as a result of the direct consideration of other equilibrium conditions; [2] – The original presentation of this procedure was for circular surfaces only.

Ordinary Method of Slices. From the above table, it is apparent that for circular failures, the Ordinary Method of Slices (Fellenius method) satisfies overall moment equilibrium, but does not satisfy individual slice moment equilibrium, or horizontal or vertical force equilibrium. Sherard et al. (1963), have suggested that the Fellenius method of slices might also be applied to non-circular surfaces; however, for noncircular surfaces that method would not, in general, satisfy any of the equilibrium conditions (Wright, 1969).

The Ordinary Method of Slices has been widely used by practicing engineers for many years because of its simplicity, but it has long been known to grossly underestimate (and in some cases overestimate) the factor of safety. Lambe and Whitman (1969) report that in some cases the Ordinary Method of Slices may underestimate the factor of safety by about 10 to 15 percent, but in other problems (particularly for noncircular slip surfaces) the error may be as much as 60 percent. With the development of high-speed computers, this approximate method has largely been replaced by more accurate methods that better satisfy equilibrium conditions. The Ordinary Method of Slices remains an acceptable method for performing hand-calculated estimates of slope stability for conditions where accurate solutions are not required.

Modified Bishop Method. The Modified Bishop Method assumes that the normal and weight forces act through a point on the center of the base of each slice and that there are no interslice shear forces. The resulting equation can be demonstrated to satisfy vertical force equilibrium as well as overall moment equilibrium for circular shear surfaces. The Modified Bishop Method is relatively simple to perform on a calculator, although the necessary iterations make it more suitable for use on a computer system. In spite of the necessary iterations, the Modified Bishop Method typically converges rapidly, therefore, it requires little computer time to perform.

Fredlund and Krahn (1977) have shown that the Modified Bishop Method typically estimates factors of safety that are typically within a few percent of those obtained from more rigorous methods that satisfy complete moment and force equilibrium.

Simplified Janbu Method. Although the simplifying assumption made in the Simplified Janbu Method is the same as that made for the Modified Bishop Method, the conditions of equilibrium that are satisfied are not the same. The Simplified Janbu Method satisfies vertical and horizontal force equilibrium for individual slices and for the overall shear surface while assuming that there are no interslice shear forces. An advantage of the Simplified Janbu Method is its suitability for the analysis of noncircular failure surfaces. While retaining a rapid computational speed, the Simplified Janbu Method yields factors of safety that are closer to those obtained by more rigorous methods (such as the Spencer Method) than those obtained from the Ordinary Method of Slices.

Spencer Method. The Spencer Method assumes that the normal forces are located at the center of the base of each slice and that all side forces are parallel. The result is an equation that satisfies complete moment and force equilibrium. Although the Spencer Method was directly applicable to a circular shear surface, the procedure may be readily extended to slip surfaces of a general shape (Wright, 1969).

Because of the complexity of the procedure, the Spencer Method is suitable only for computer-aided slope stability analyses. Although the Spencer Method typically yields a relatively accurate estimate of the factor of safety for a slope, its solution requires several iterations. Consequently, considerable time is needed to perform the analyses on a personal computer. Therefore, the Spencer Method is commonly used to refine the factor of safety for a critical failure plane that has been located by a search, which has used a more time-efficient method of analysis such as the Modified Bishop Method or Simplified Janbu procedure.

ANALYSES PERFORMED

Introduction. Analyses were performed to calculate the stability of the earth materials exposed in the slope. It is necessary to know the: 1) surface and subsurface geometry, 2) soil properties (unit weight and shear strength of the soil materials present), and 3) phreatic water level (groundwater) conditions.

Surface and Subsurface Geometry. Data for the surface geometry of the project area was obtained using information presented by VESTRA (2016) and topographic data from Falls & Hardin (2005). Subsurface information was projected from Falls & Hardin (2005) and Young (1978).

Engineering Properties. A summary and discussion of rock mass strength values is presented in the text of the report.

Piezometric Water Level. The elevations of groundwater beneath the site are discussed in the text of the report.

Results of Analyses. The following table presents the conditions evaluated and results of the stability evaluations:

RESULTS OF STABILITY ANALYSES				
Cross Section	**Slope Condition Evaluated**	**Strength Values Used**[1]	**Factor of Safety**[2]	**File Name**
B-B’	Existing Topography, Static	Backcalculated	1.25	B-B’_Existing_BCStrengths
B-B’	Proposed 1:1 Highwall, Static	Backcalculated	1.23	B-B’_Proposed 1-1_BCStrengths
B-B’	Proposed 1:1 Highwall, Pseudostatic	Backcalculated	0.87	B-B’_Proposed 1-1_BCStrengthsPS
B-B’	Proposed 1:1 Highwall, Static	TVCE (2015)	1.65	B-B’_Proposed 1-1_EnchiladaStrengths
B-B’	Proposed 1:1 Highwall, Pseudostatic	TVCE (2015)	1.16	B-B’_Proposed 1-1_EnchiladaStrengthsPS
C-C’	Existing Topography, Static	Backcalculated	1.26	C-C’_Existing_BCStrengths
C-C’	Proposed 1:1 Highwall, Static	Backcalculated	1.13	C-C’_Proposed 1-1_BCStrengths
C-C’	Proposed 1:1 Highwall, Pseudostatic	Backcalculated	0.87	C-C’_Proposed 1-1_BCStrengthsPS
C-C’	Proposed 1:1 Highwall, Static	TVCE (2015)	1.07	C-C’_Proposed 1-1_EnchiladaStrengths
C-C’	Proposed 1:1 Highwall, Pseudostatic	TVCE (2015)	0.82	C-C’_Proposed 1-1_EnchiladaStrengthsPS
C-C’	Proposed 1:1 Highwall, Static, modeled with no upper ascending slope	Backcalculated	1.43	C-C’_Proposed 1-1_BCStrengths_NoSlopeAbove
C-C’	Proposed 1:1 Highwall, Static, modeled with no upper ascending slope	TVCE (2015)	1.11	C-C’_Proposed 1-1_EnchiladaStrengths_NoSlopeAbove
C-C’	Proposed 1:1 Highwall, Static, modeled with no upper ascending slope, dry	TVCE (2015)	1.35	C-C’_Proposed 1-1_EnchiladaStrengths_NoSlopeAbove
C-C’	Proposed 1:1 Highwall, Static, modeled with depressed phreatic surface	Backcalculated	1.26	C-C’_Proposed 1.5-1_BCStrengths
C-C’	Proposed 1:1 Highwall, Pseusdostatic, modeled with depressed phreatic surface	Backcalculated	1.00	C-C’_Proposed 1.5-1_BCStrengths
D-D’	Existing Topography, Static	Backcalculated	1.25	D-D’_Existing_BCStrengths
D-D’	Proposed 1:1 Highwall, Static	Backcalculated	1.23	D-D’_Proposed 1-1_BCStrengths
D-D’	Proposed 1:1 Highwall, Pseudostatic	Backcalculated	0.89	D-D’_Proposed 1-1_BCStrengthsPS
D-D’	Proposed 1:1 Highwall, Static	TVCE (2015)	1.24	D-D’_Proposed 1-1_EnchiladaStrengths
D-D’	Proposed 1:1 Highwall, Pseudostatic	TVCE (2015)	0.96	D-D’_Proposed 1-1_EnchiladaStrengthsPS

1 – Backcalculated: C=13,650 psf, Ø= 20°; TVCE (2015): C=2,000 psf, Ø= 40°.
2 – FOS thresholds for this study: static = 1.25 & pseudostatic = >1.

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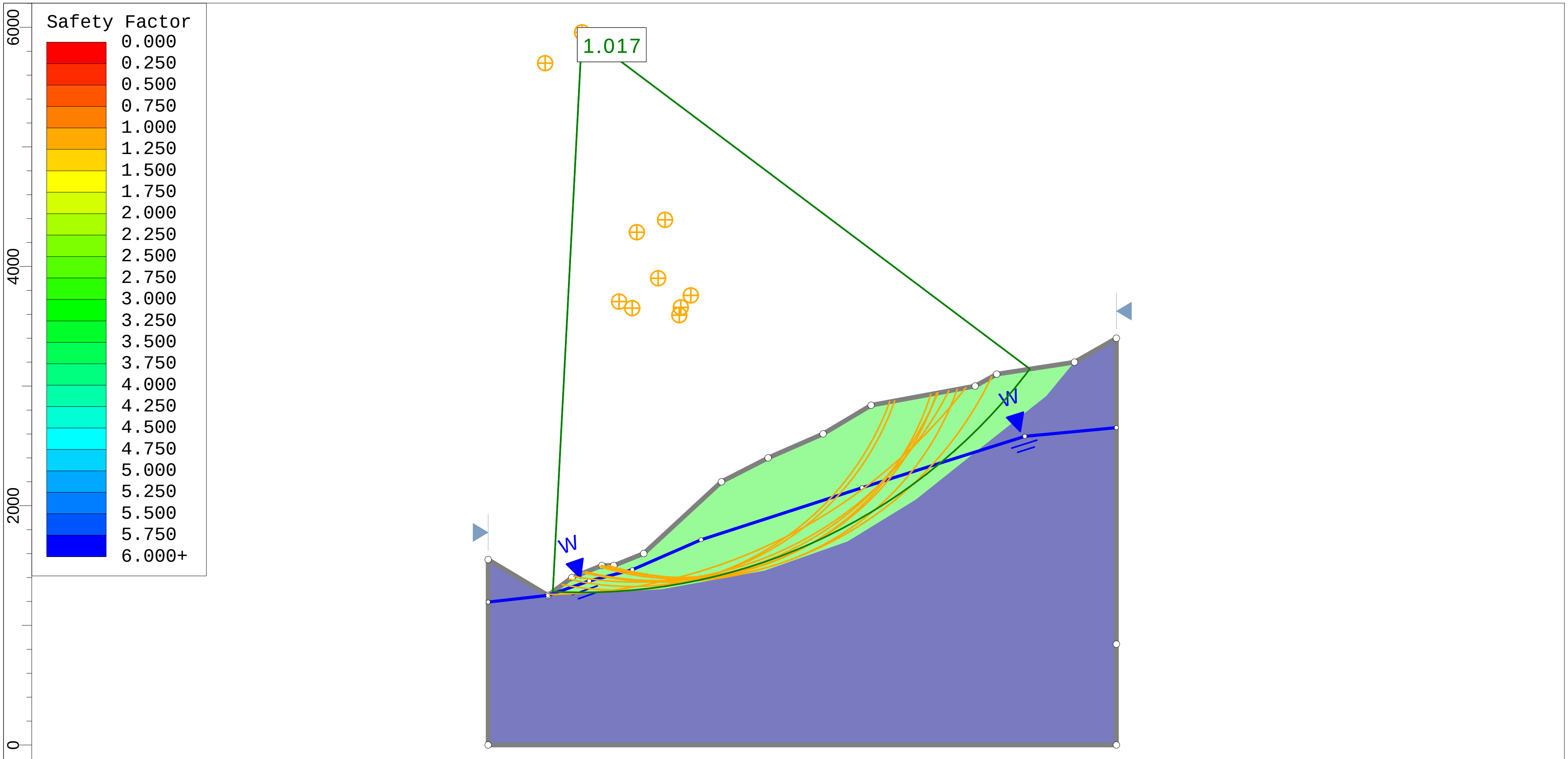
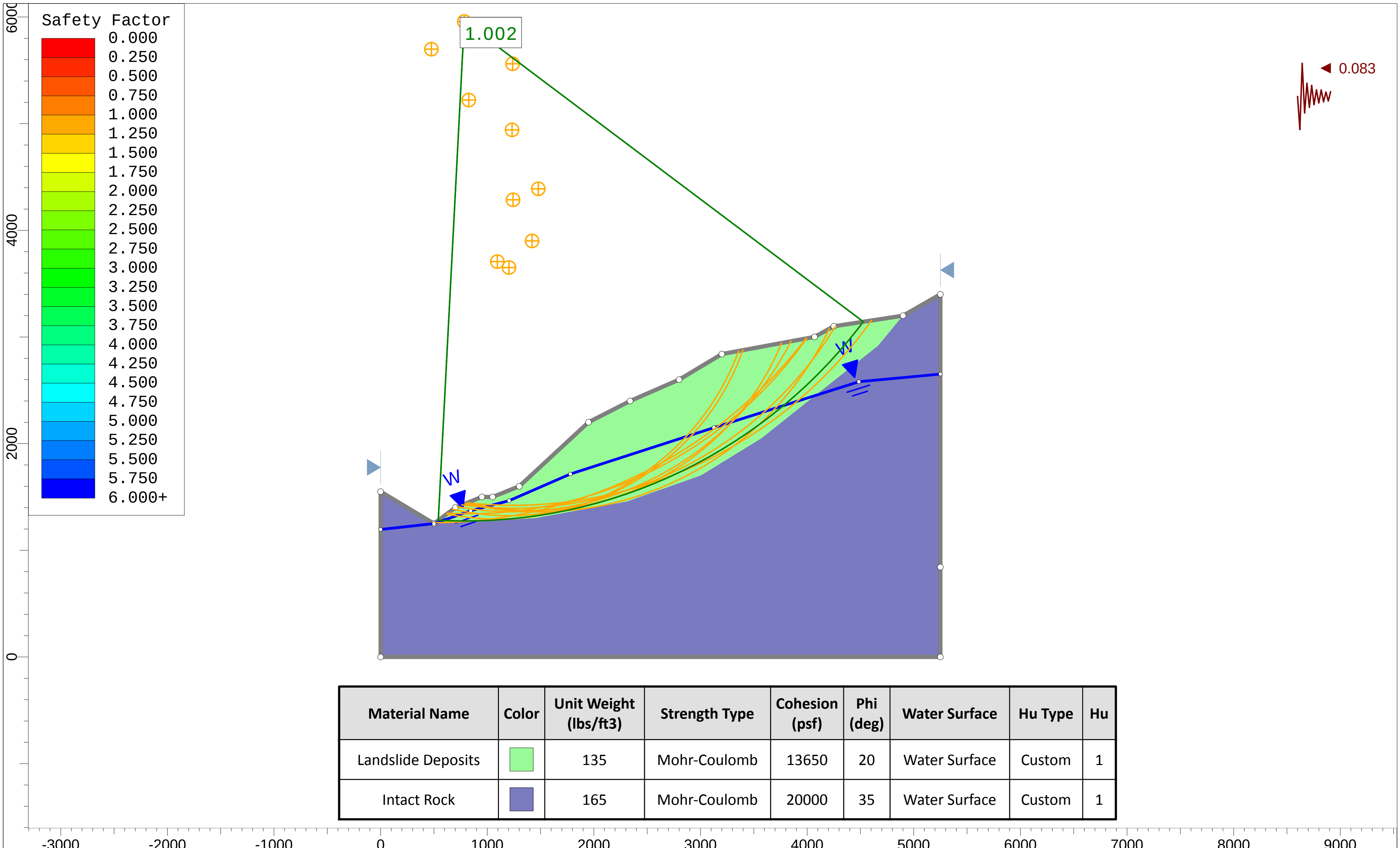


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	15	Water Surface	Custom	1
Intact Rock		165	Mohr-Coulomb	20000	35	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry		
Analysis Description	Backcalculated rock mass strength, static		
Drawn By J. Bianchin	*Scale* 1:14909	*Company*	Bajada Geosciences, inc.
Date	4/5/2018, 3:00:18 PM	*File Name*	Brown_RMBack_Static.slim

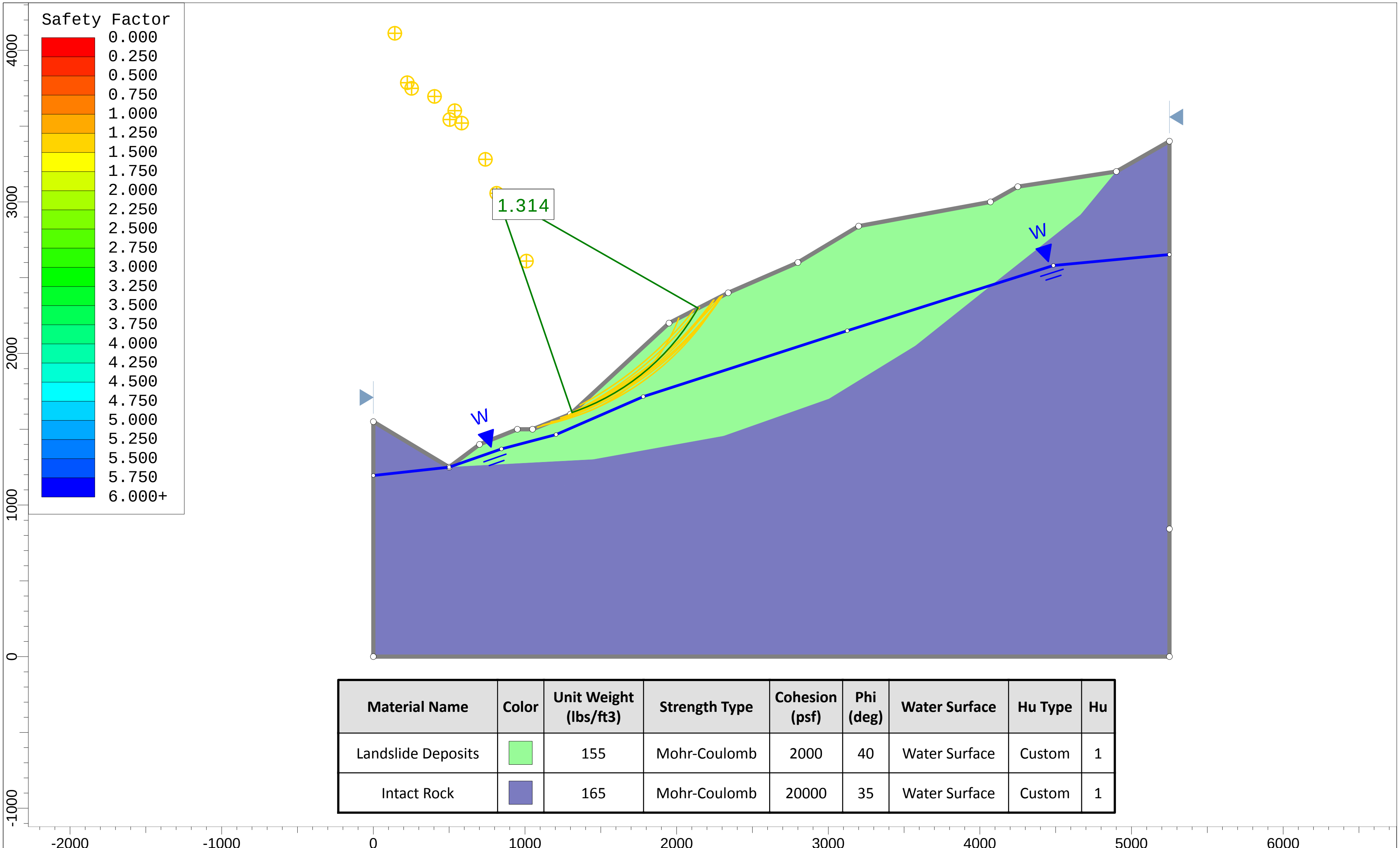


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		165	Mohr-Coulomb	20000	35	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry		
Analysis Description	Backcalculated rock mass strength, Pseudostatic Loading, M5.4 2008		
Drawn By	J. Bianchin	*Scale* 1:14942	*Company* Bajada Geosciences, inc.
Date	4/5/2018, 3:00:18 PM		*File Name* Brown_RMBack_PSLoading.slim

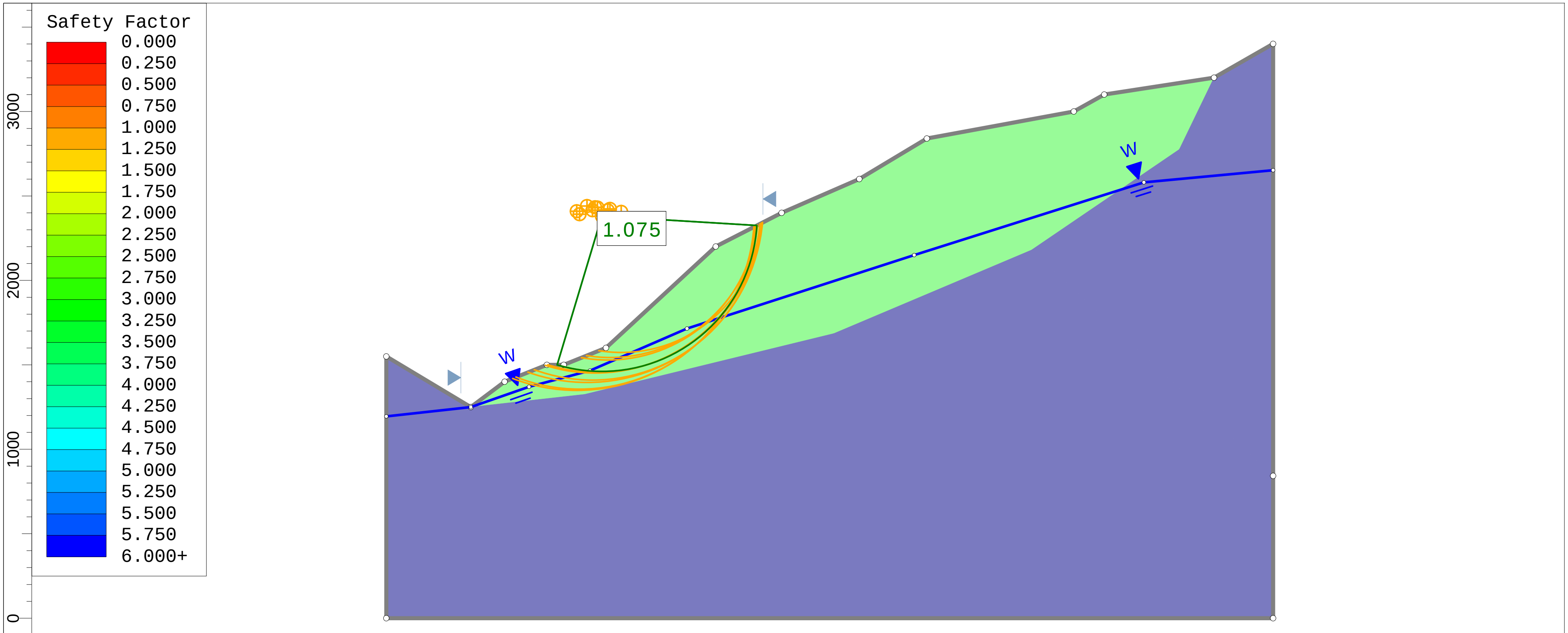


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		155	Mohr-Coulomb	2000	40	Water Surface	Custom	1
Intact Rock		165	Mohr-Coulomb	20000	35	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry		
Analysis Description	Backcalculated rock mass strength, static		
Drawn By J. Bianchin	*Scale* 1:10504	*Company*	Bajada Geosciences, inc.
Date	4/5/2018, 3:00:18 PM	*File Name*	Brown_RMBack_Static_EnchiladaStrength.slim

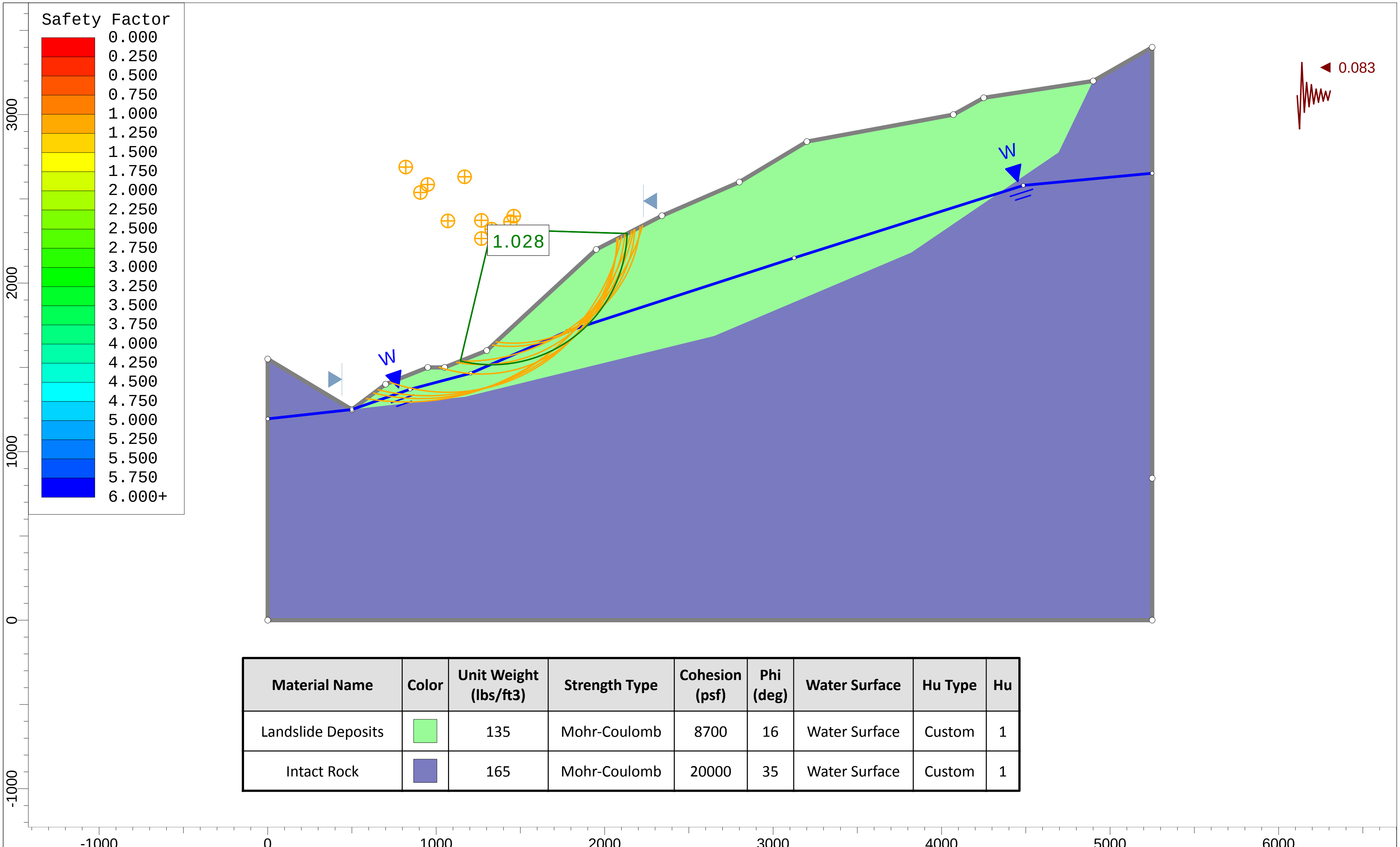


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	8700	15	Water Surface	Custom	1
Intact Rock		165	Mohr-Coulomb	20000	35	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry		
Analysis Description	Backcalculated rock mass strength, Galice, static		
Drawn By J. Bianchin	*Scale* 1:10562	*Company*	Bajada Geosciences, inc.
Date	4/5/2018, 3:00:18 PM	*File Name*	Brown_WestSlope_RMBack_Static.slim

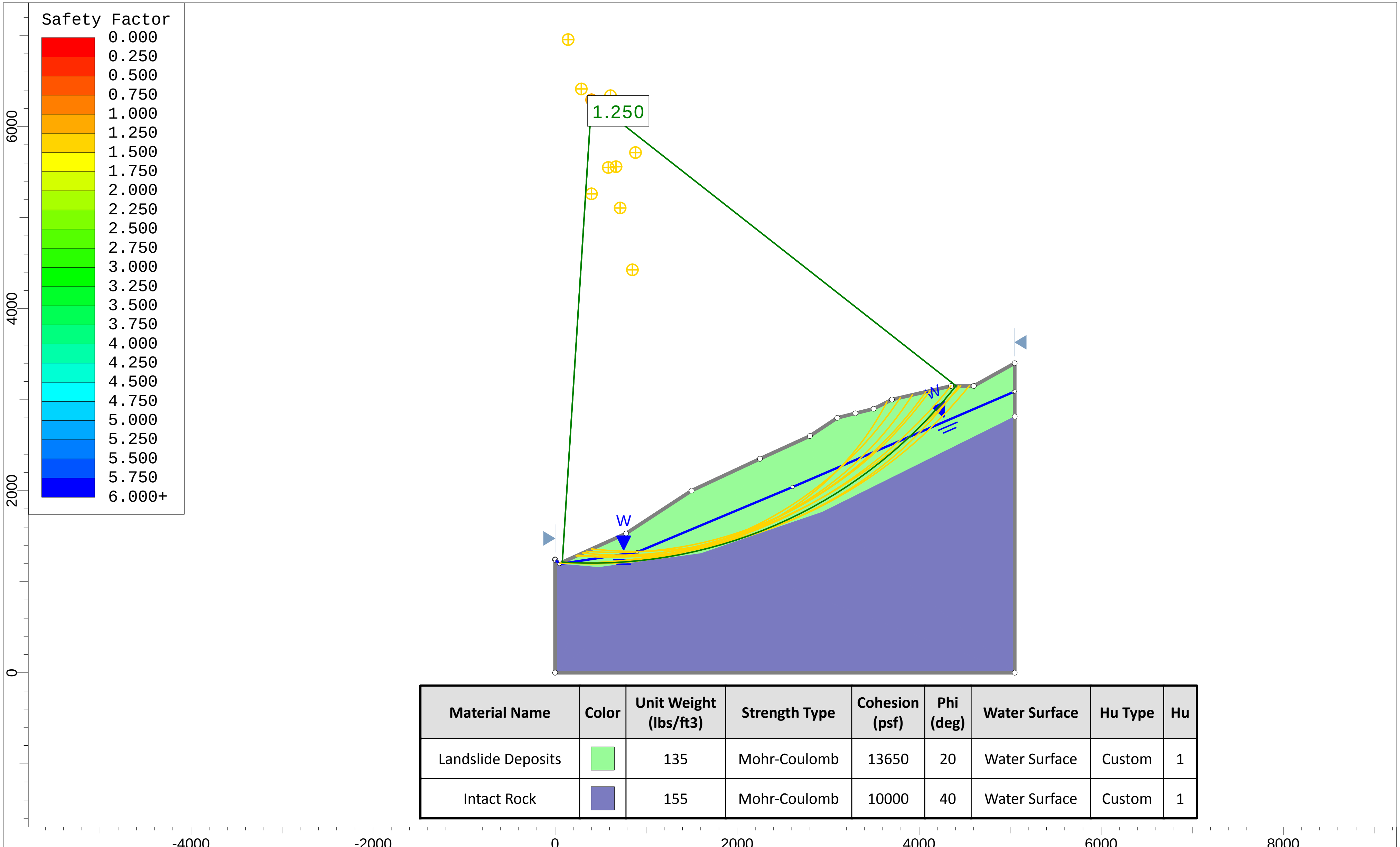


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	8700	16	Water Surface	Custom	1
Intact Rock		165	Mohr-Coulomb	20000	35	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry		
Analysis Description	Backcalculated rock mass strength, Galice, Pseudostatic, M5.4 2008		
Drawn By J. Bianchin	*Scale* 1:9454	*Company*	Bajada Geosciences, Inc.
Date	4/5/2018, 3:00:18 PM	*File Name*	Brown_WestSlope_RMBack_SPSLoading.slim

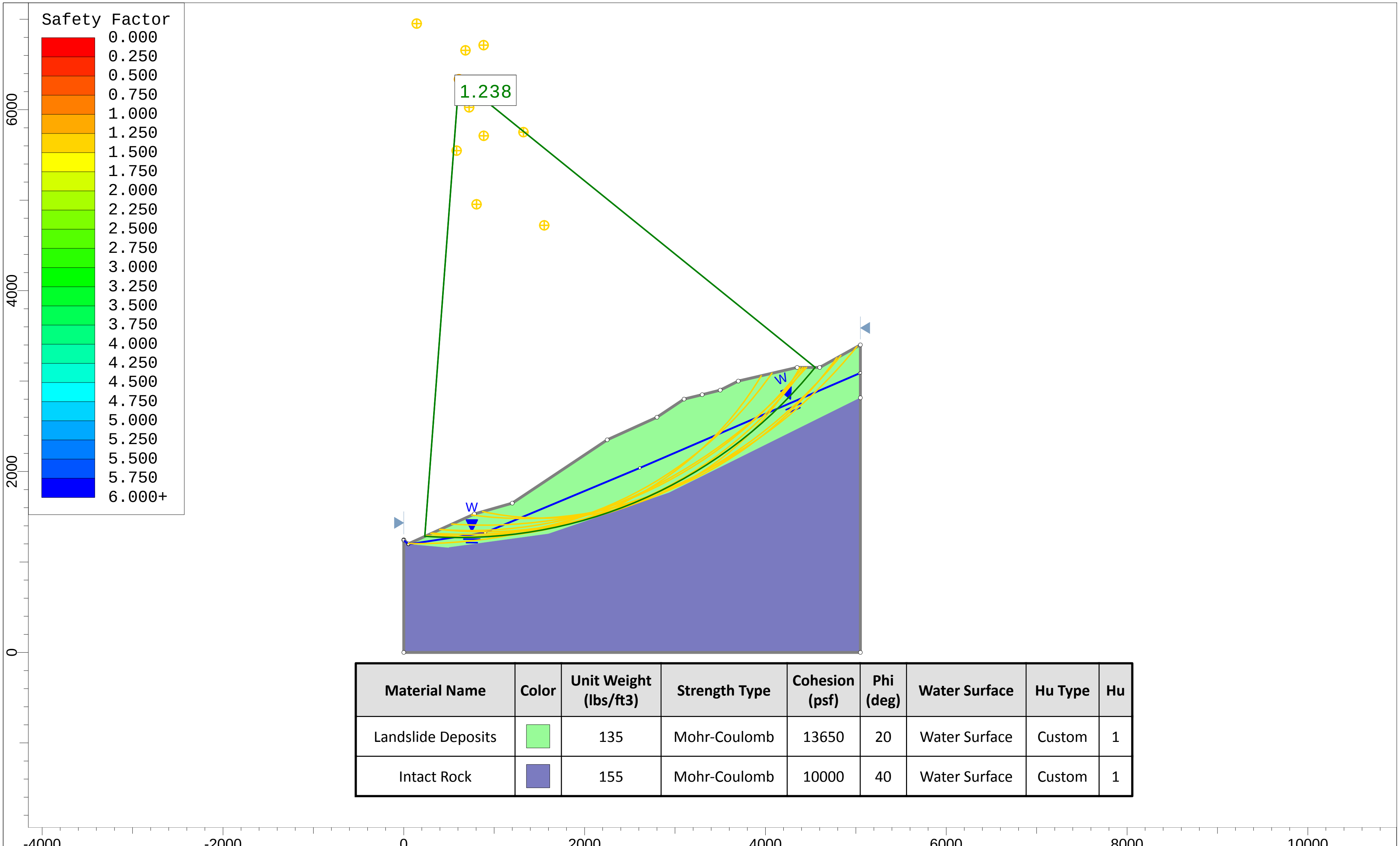


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	10000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review		
Analysis Description	Section B-B', Static, Existing Conditions, Backcalculated Strengths		
Drawn By J.Bianchin	*Scale* 1:17501	*Company*	Bajada Geosciences, inc.
Date	4/6/2018, 11:25:07 AM	*File Name*	B-B'_Existing_BCStrengths.slim

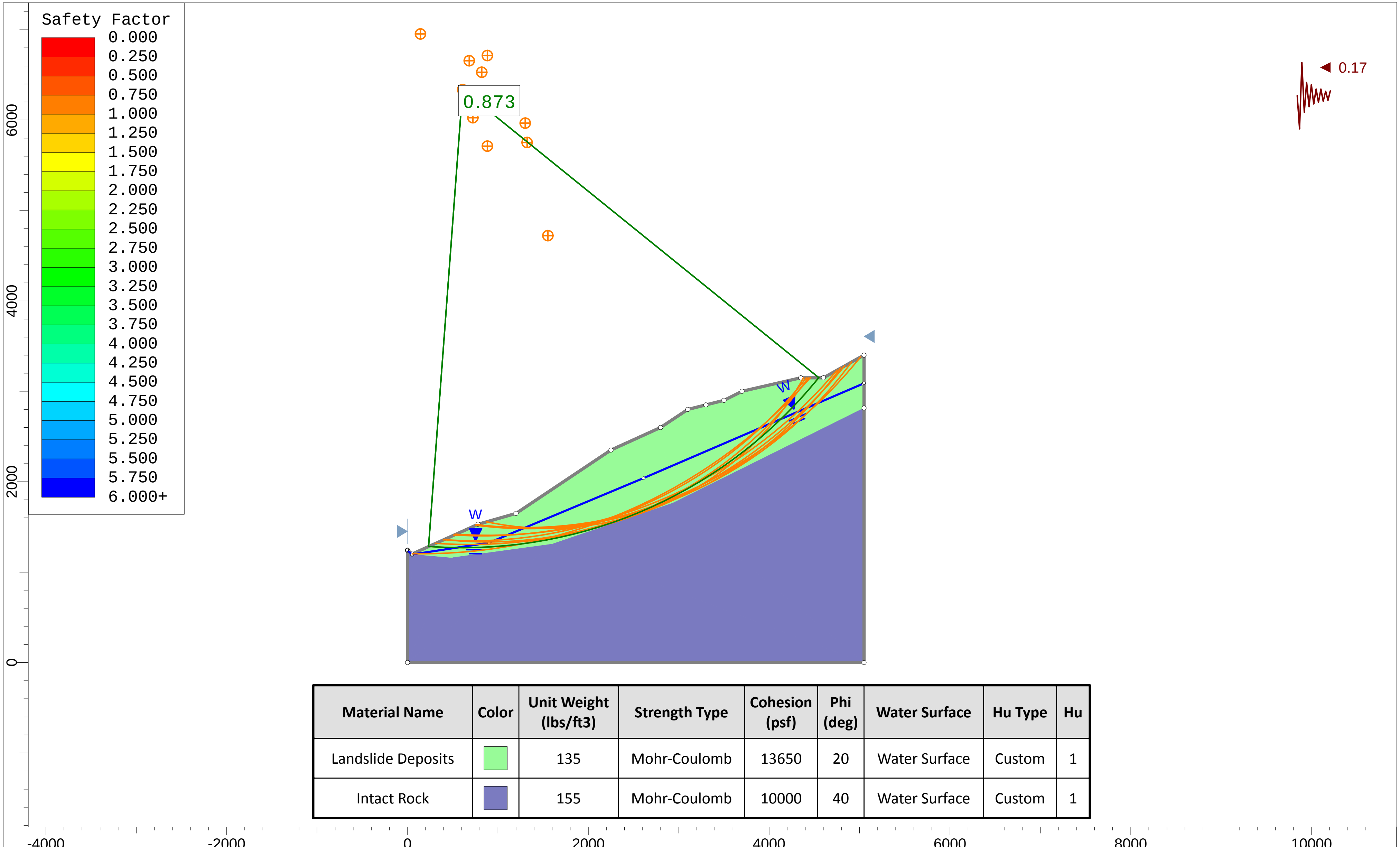


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	10000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review
Analysis Description	Section B-B', Static, Proposed 1:1 Slope, Backcalculated Strengths
Drawn By	J.Bianchin
Scale	1:17619
Company	Bajada Geosciences, inc.
Date	4/6/2018, 11:25:07 AM
File Name	B-B'_Proposed1-1_BCStrengths.slim

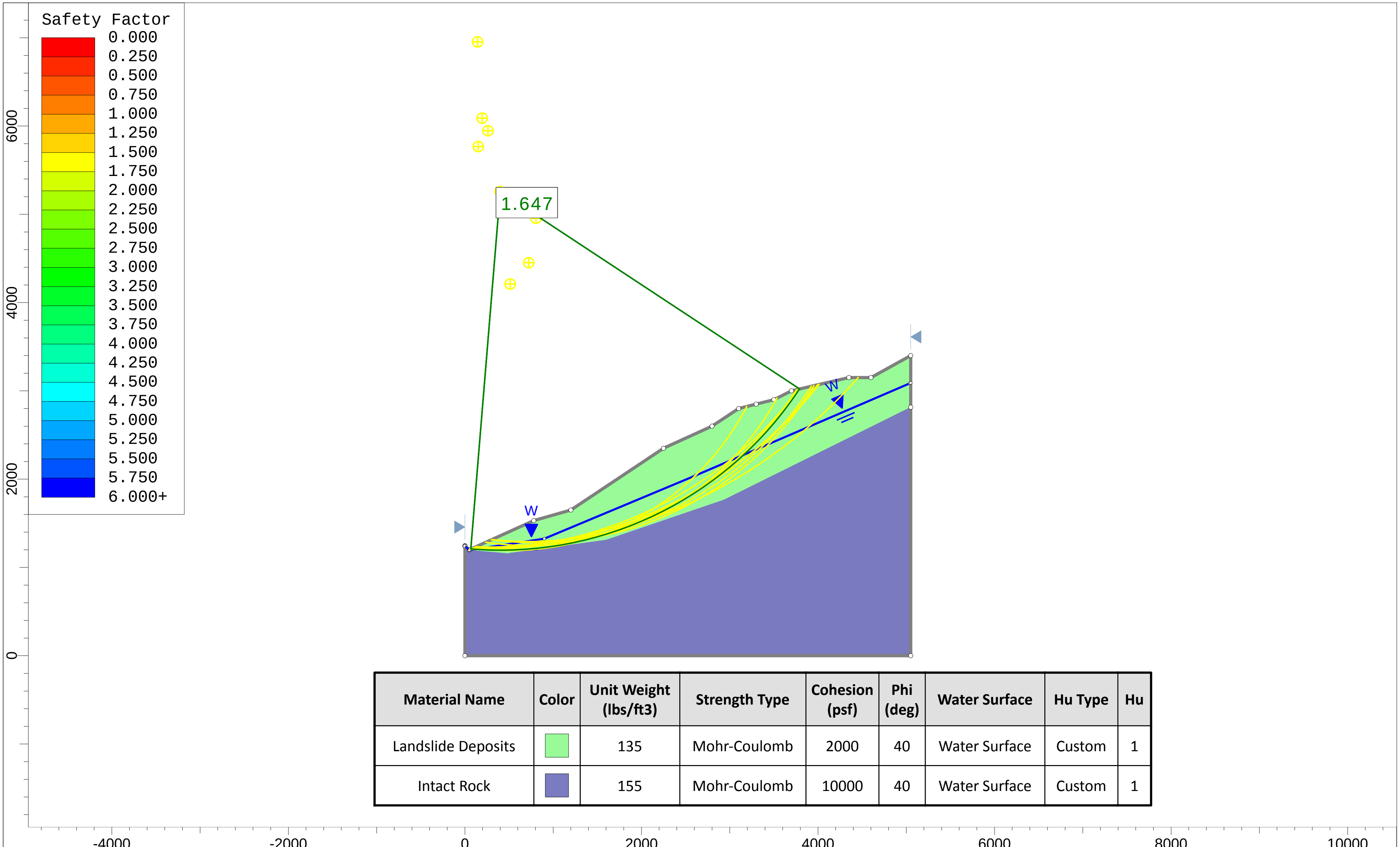


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	10000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review		
Analysis Description	Section B-B', Pseudostatic, Proposed 1:1 Slope, Backcalculated Strengths		
Drawn By	J.Bianchin	*Scale* 1:17619	*Company* Bajada Geosciences, inc.
Date	4/6/2018, 11:25:07 AM		*File Name* B-B'_Proposed1-1_BCStrengthsPS.slim

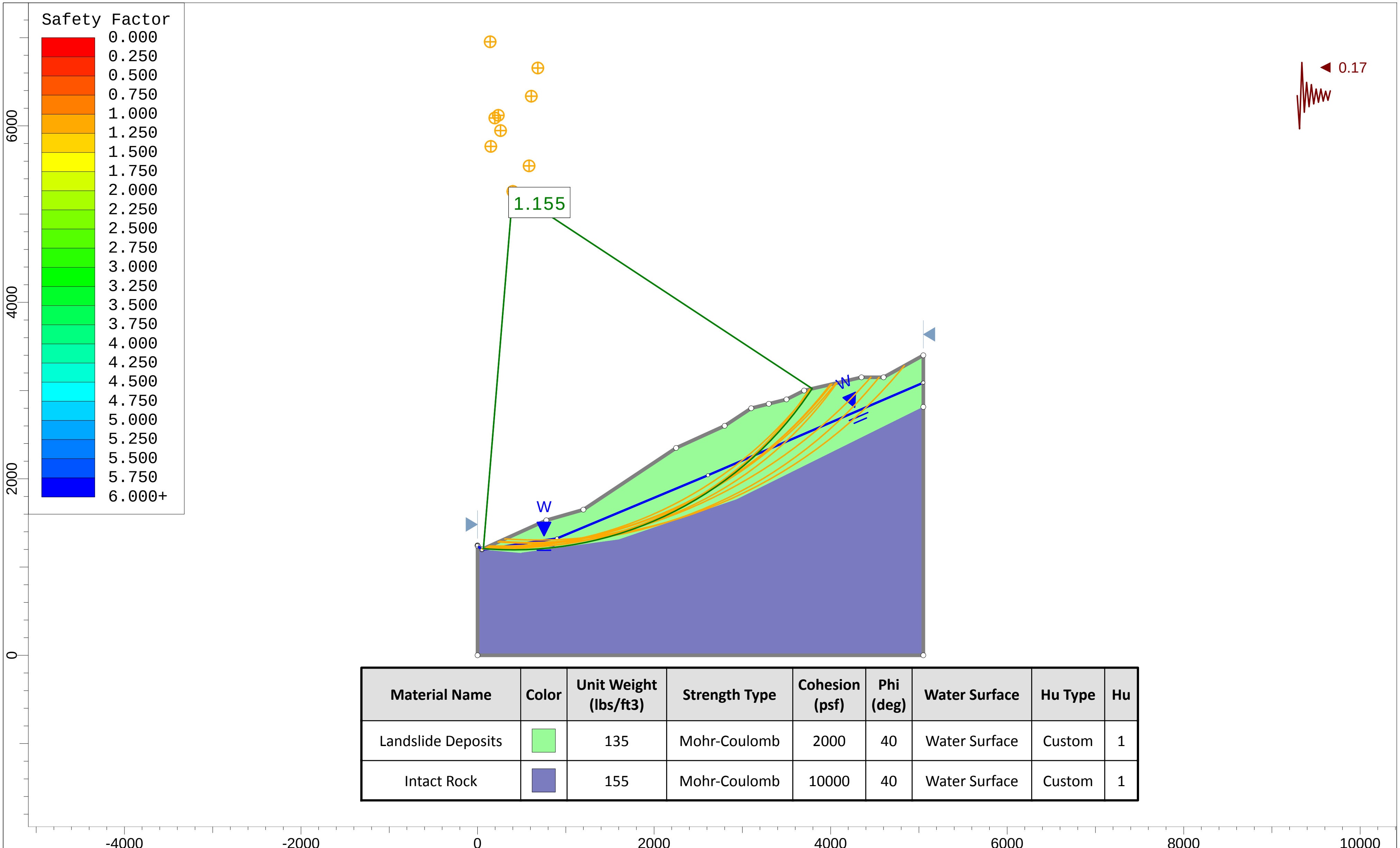


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	2000	40	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	10000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review
Analysis Description	Section B-B', Static, Proposed 1:1 Slope, C=2000 psf, Phi=40
Drawn By	J.Bianchin
Scale	1:18046
Company	Bajada Geosciences, inc.
Date	4/6/2018, 11:25:07 AM
File Name	B-B'_Proposed1-1_EnchiladaStrengths.slim

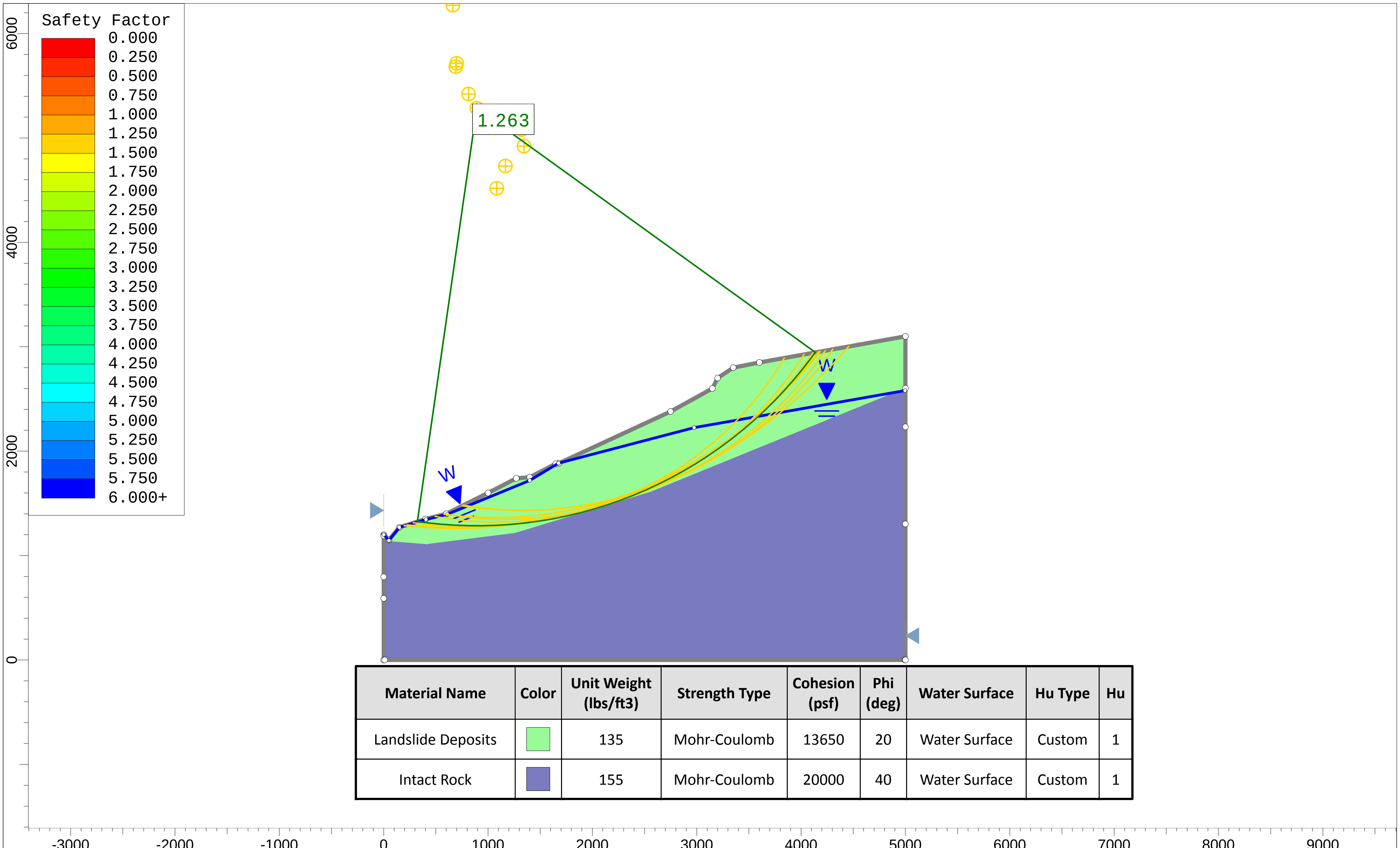


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	2000	40	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	10000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review		
Analysis Description	Section B-B', Pseudostatic, Proposed 1:1 Slope, C=2000 psf, Phi=40		
Drawn By J.Bianchin	*Scale* 1:18046	*Company*	Bajada Geosciences, inc.
Date	4/6/2018, 11:25:07 AM	*File Name*	B-B'_Proposed1-1_EnchiladaStrengthsPS.slim

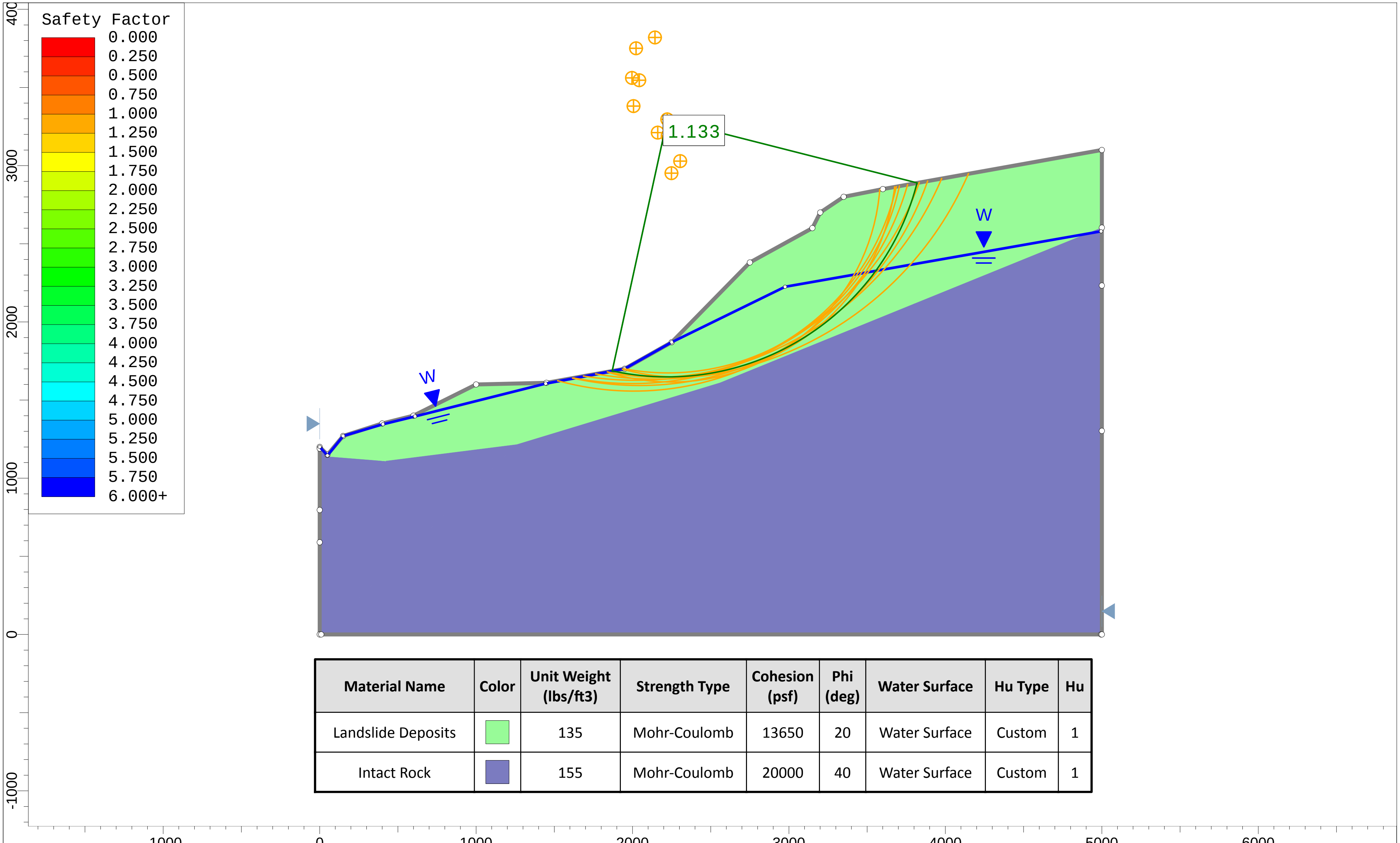


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	20000	40	Water Surface	Custom	1

BAJADA
Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review
Analysis Description	Section C-C', Existing Slope, Static, Observed Phreatic Surface
Drawn By	J.Bianchin
Scale	1:15265
Company	Bajada Geosciences, Inc.
Date	4/6/2018, 9:33:53 AM
File Name	C-C'_Existing_BCStrengths.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	20000	40	Water Surface	Custom	1

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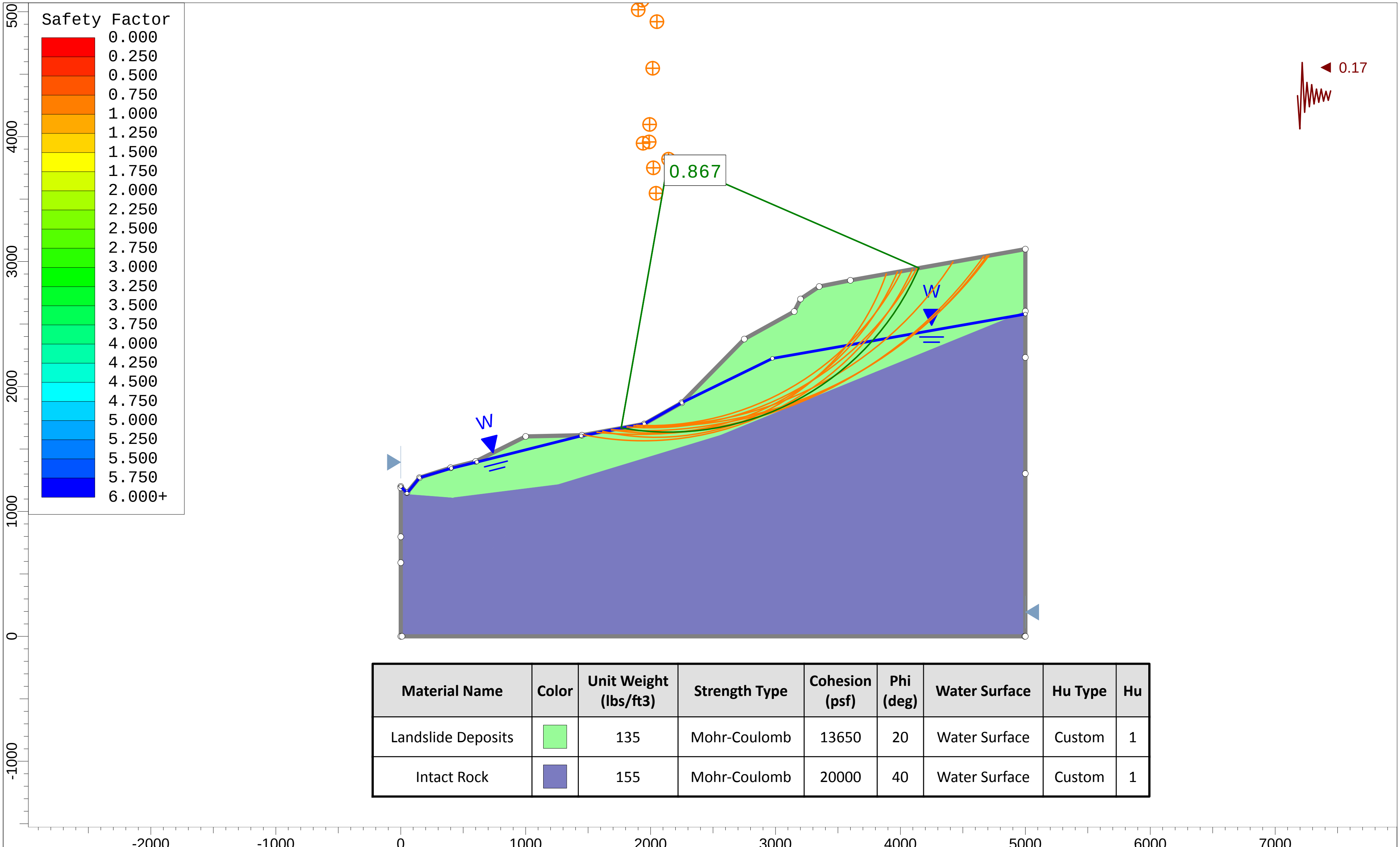
SLIDEINTERPRET 7.030

Project	Brown Quarry Review		
Analysis Description	Section C-C', proposed 1:1 Slope, Static, Observed Phreatic Surface		
Drawn By J.Bianchin	*Scale* 1:10182	*Company*	Bajada Geosciences, Inc.
Date	4/6/2018, 9:33:53 AM	*File Name*	C-C'_Proposed1-1_BCStrengths.slim

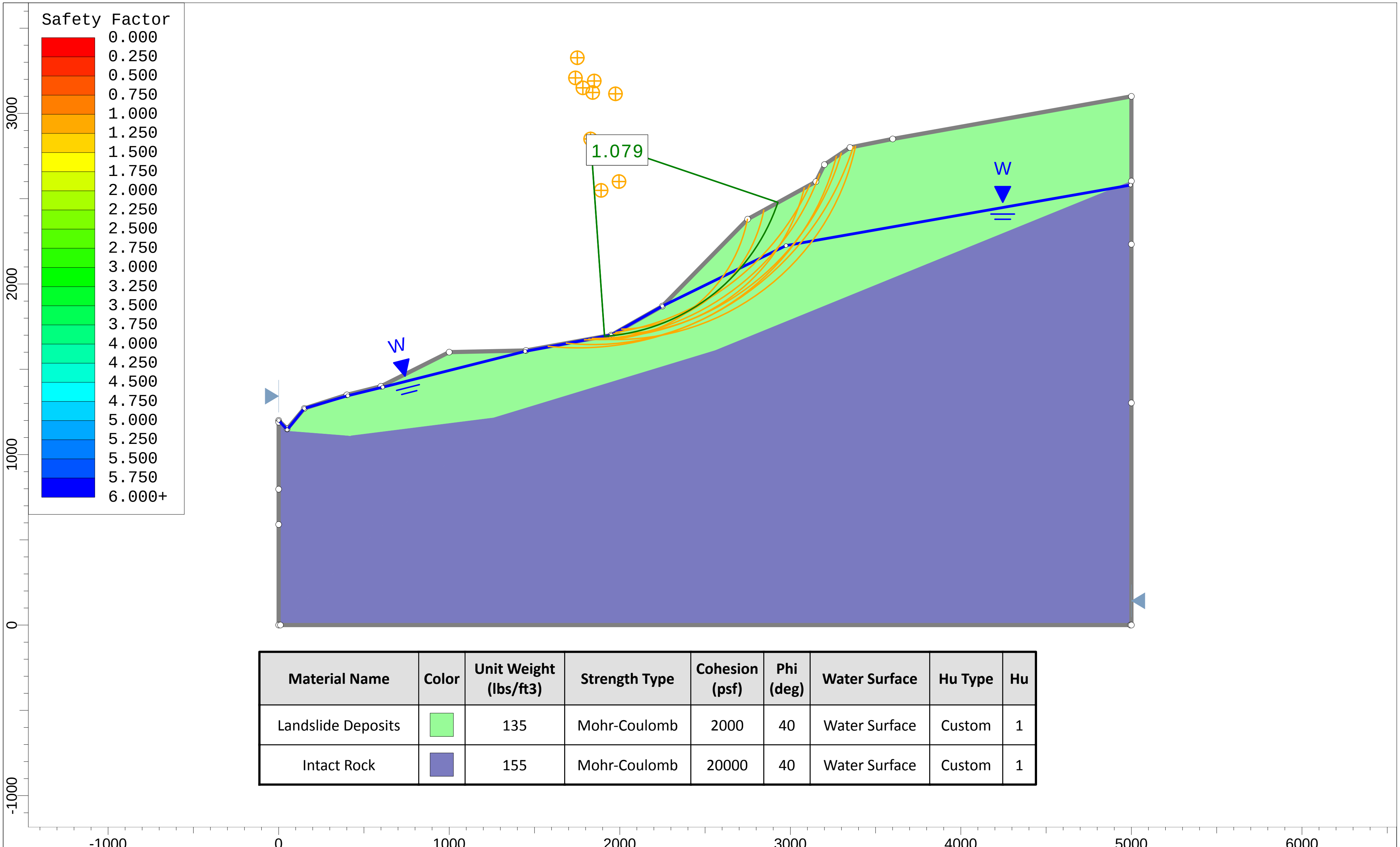


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	20000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review		
Analysis Description	Section C-C', proposed 1:1 Slope, Pseudostatic, Observed Phreatic Surface		
Drawn By J.Bianchin	*Scale* 1:12754	*Company*	Bajada Geosciences, Inc.
Date	4/6/2018, 9:33:53 AM	*File Name*	C-C'_Proposed1-1_BCStrengthsPS.slim

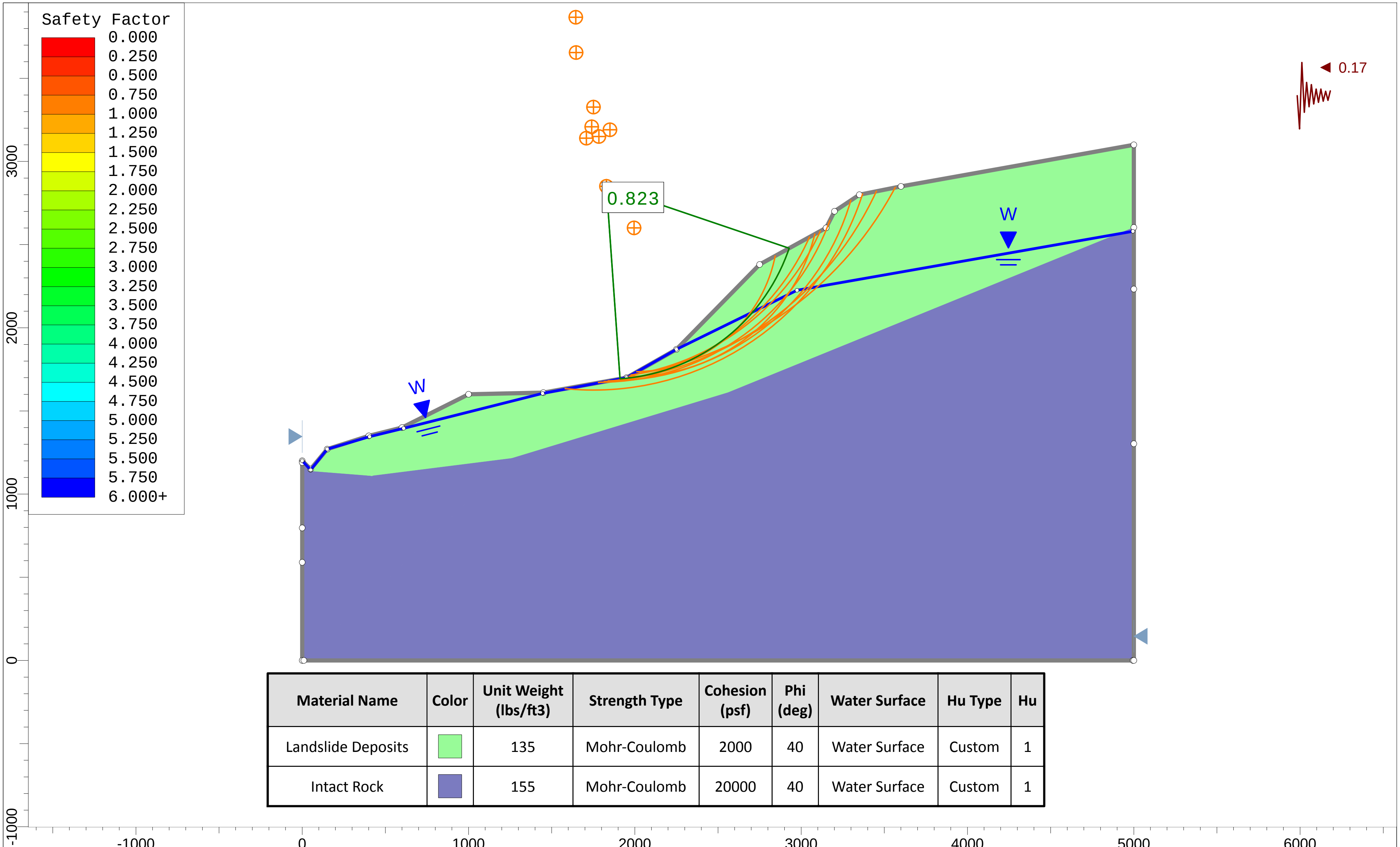


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	2000	40	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	20000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review		
Analysis Description	Section C-C', proposed 1:1 Slope, Static, Observed Phreatic Surface, C=2000,Phi=40		
Drawn By	J.Bianchin	*Scale*	1:9340
Company	Bajada Geosciences, Inc.		
Date	4/6/2018, 9:33:53 AM	*File Name*	C-C'_Proposed1-1_EnchiladaStrengths.slim

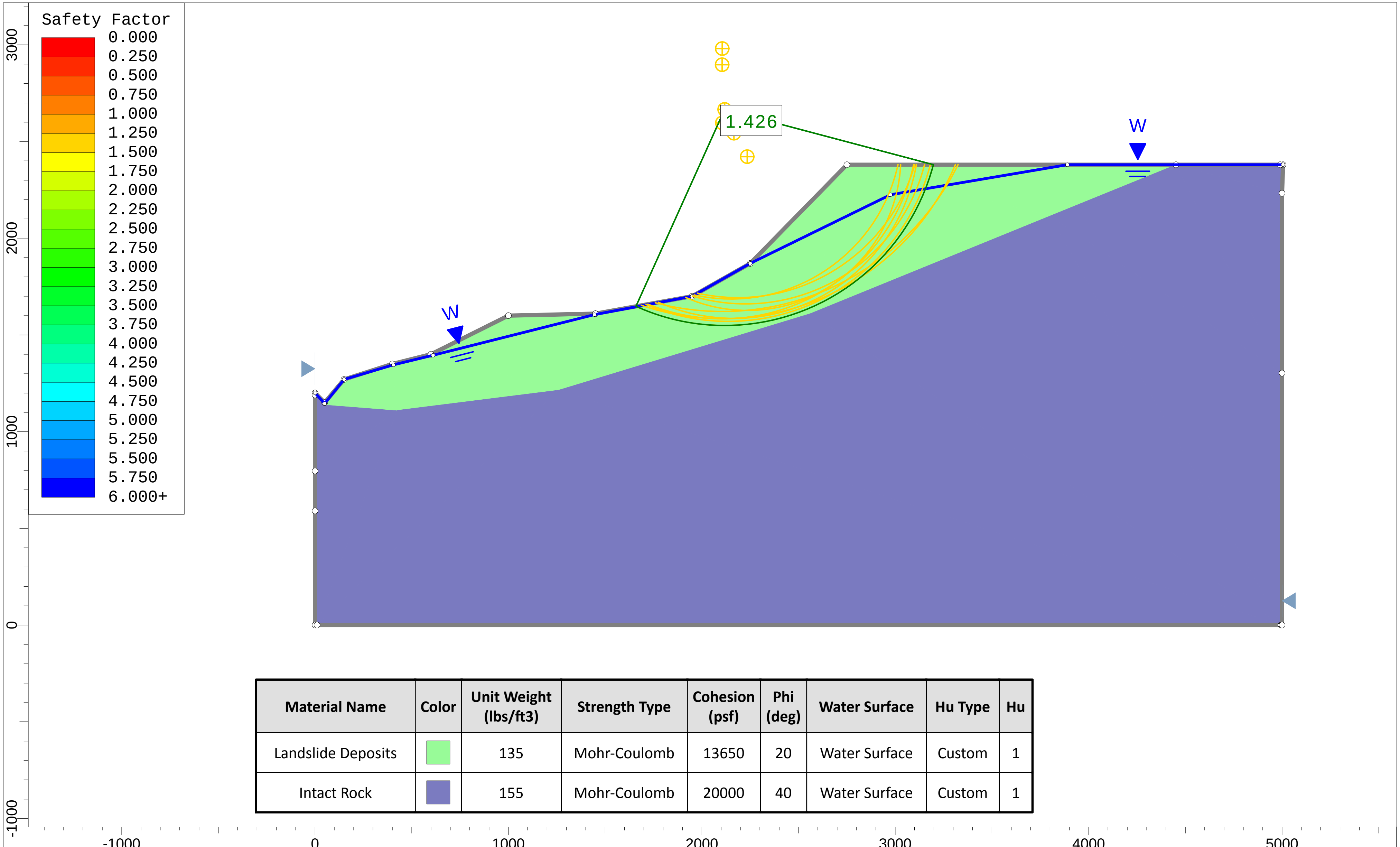


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	2000	40	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	20000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review
Analysis Description	Section C-C', proposed 1:1 Slope, Pseudostatic, Observed Phreatic Surface, C=2000,Phi=40
Drawn By	J.Bianchin
Scale	1:9578
Company	Bajada Geosciences, Inc.
Date	4/6/2018, 9:33:53 AM
File Name	C-C'_Proposed1-1_EnchiladaStrengthsPS.slim

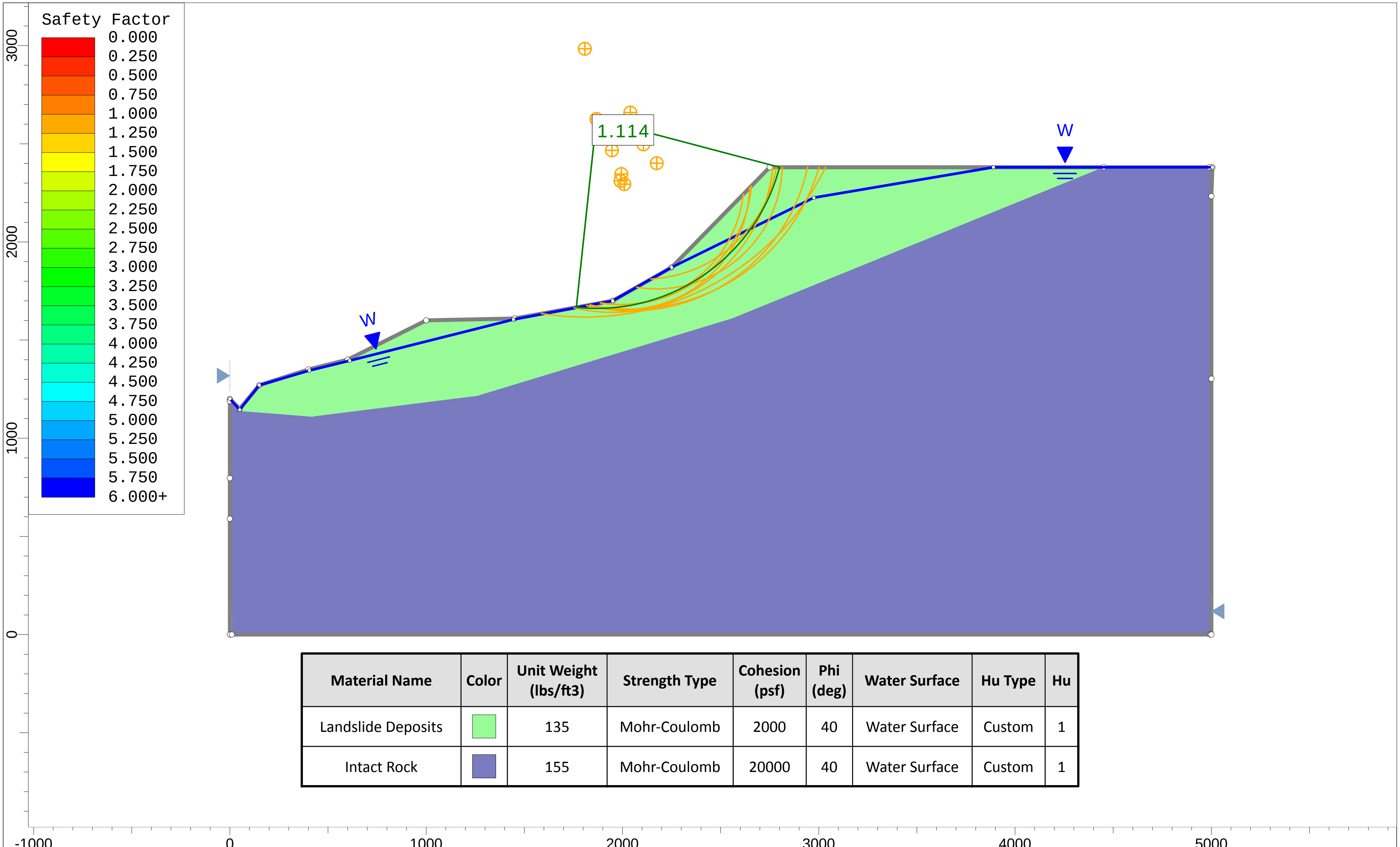


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	20000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

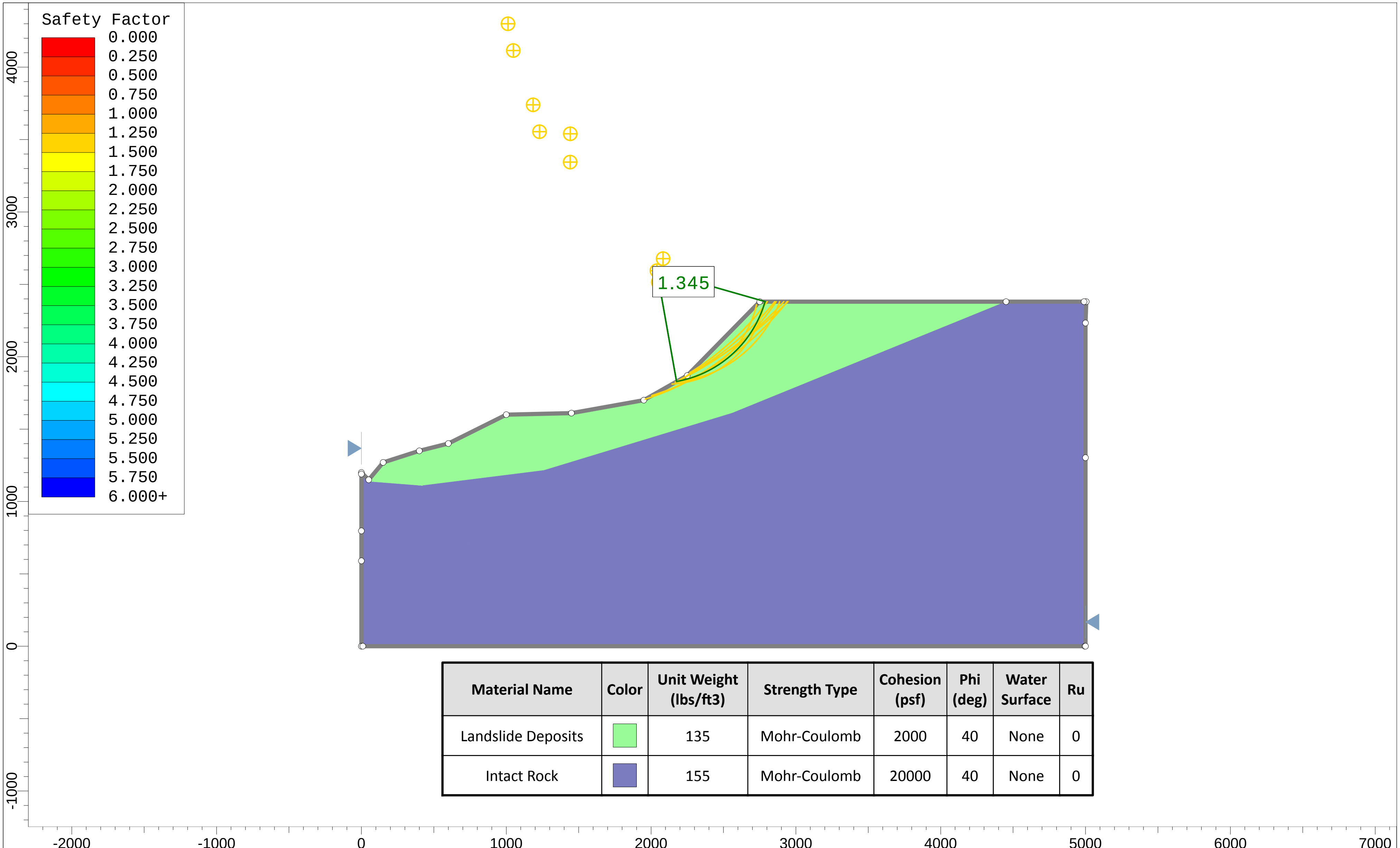
SLIDEINTERPRET 7.030

Project	Brown Quarry Review		
Analysis Description	Section C-C', proposed 1:1 Slope, Static, Observed Phreatic Surface		
Drawn By J.Bianchin	*Scale* 1:8236	*Company*	Bajada Geosciences, Inc.
Date	4/6/2018, 9:33:53 AM	*File Name*	C-C'_Proposed1-1_BCStrengths_NoSlopeAbove.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	2000	40	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	20000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc. SLIDEINTERPRET 7.030	*Project* Brown Quarry Review		
	Analysis Description Section C-C', proposed 1:1 Slope, Static, C=2000 psf, Phi=40, No Upper Slope		
	Drawn By J.Bianchin	*Scale* 1:8115	*Company* Bajada Geosciences, Inc.
	Date 4/6/2018, 9:33:53 AM		*File Name* C-C'_Proposed1-1_EnchiladaStrengths_NoSlopeAbove.slim

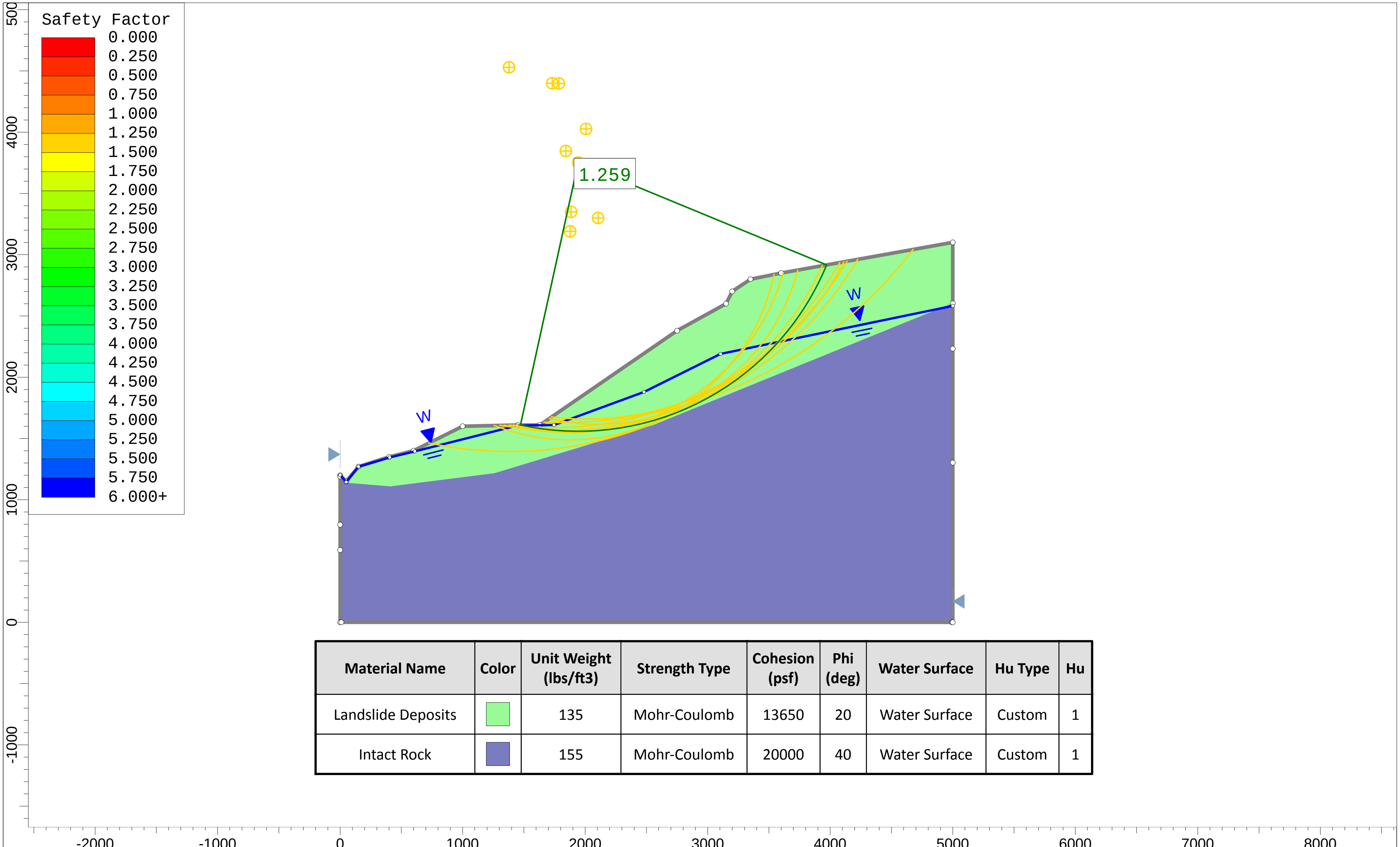


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Ru
Landslide Deposits		135	Mohr-Coulomb	2000	40	None	0
Intact Rock		155	Mohr-Coulomb	20000	40	None	0

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review
Analysis Description	Section C-C', proposed 1:1 Slope, Static, C=2000 psf, Phi=40, No Upper Slope, Dry
Drawn By	J.Bianchin
Scale	1:10999
Company	Bajada Geosciences, Inc.
Date	4/6/2018, 9:33:53 AM
File Name	C-C'_Proposed1-1_EnchiladaStrengths_NoSlopeAbove_Dry.slim

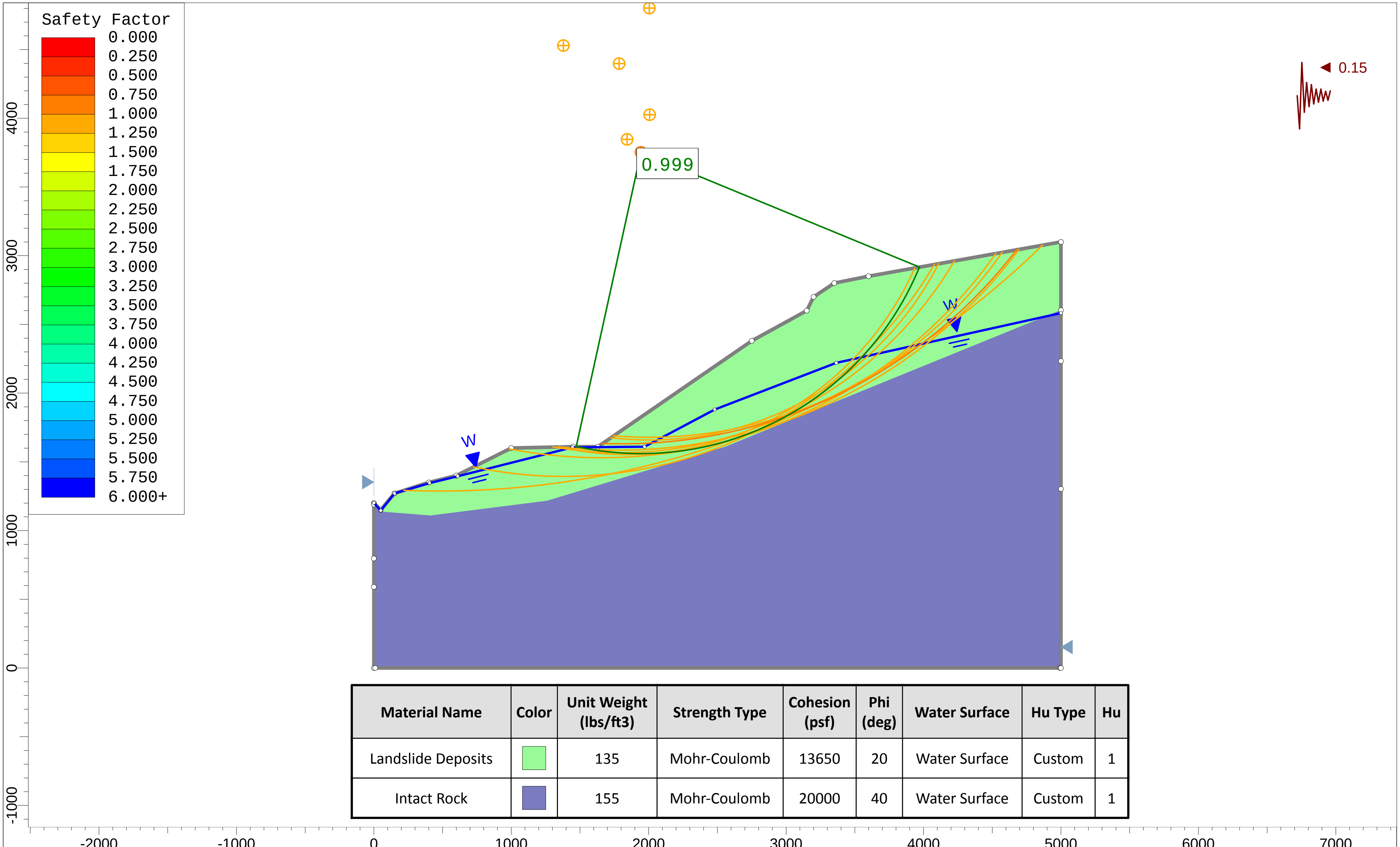


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	20000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.033

Project	Brown Quarry Review
Analysis Description	Section C-C', proposed 1.5:1 Slope, Static, Drained Slope Condition
Drawn By	J.Bianchin
Scale	1:13001
Company	Bajada Geosciences, Inc.
Date	4/6/2018, 9:33:53 AM
File Name	C-C'_Proposed1.5-1_BCStrengths.slim

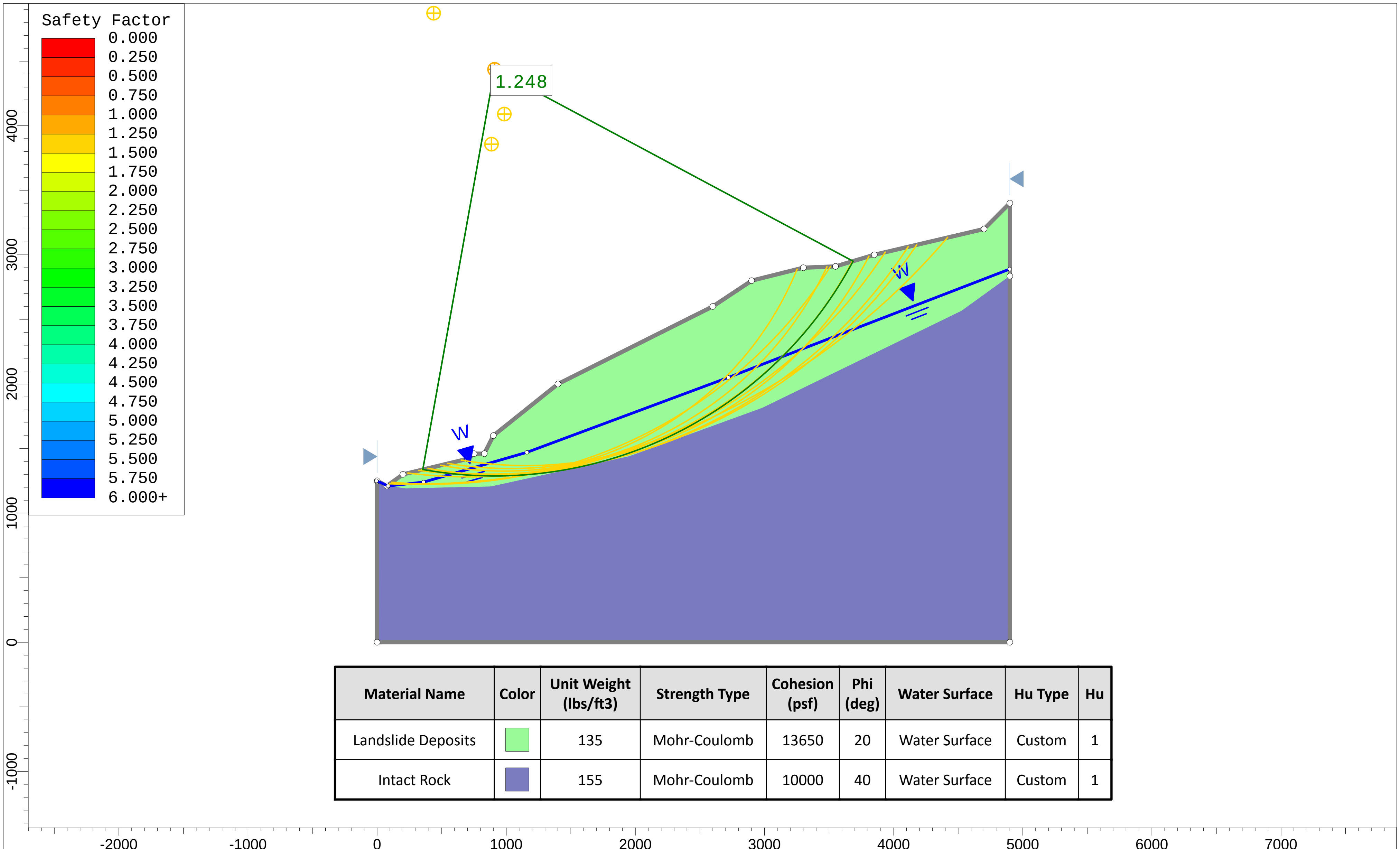


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	20000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.033

Project	Brown Quarry Review		
Analysis Description	Section C-C', proposed 1.5:1 Slope, Pseusdostatic, Drained Slope Condition		
Drawn By	J.Bianchin	*Scale*	1:11592
Company	Bajada Geosciences, Inc.		
Date	4/6/2018, 9:33:53 AM	*File Name*	C-C'_Proposed1.5-1_BCStrengthsPS.slim

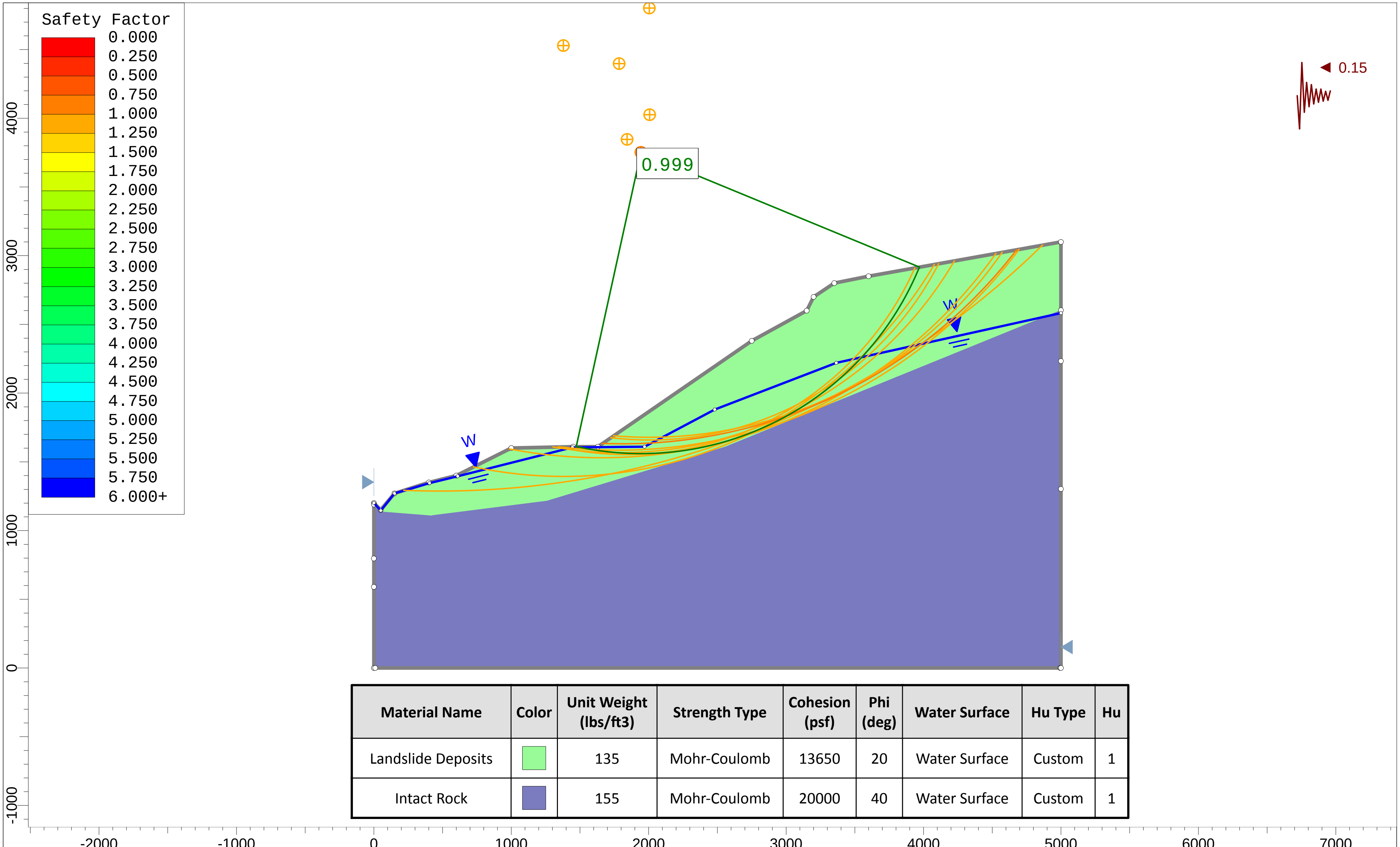


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	10000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review
Analysis Description	Section D-D', Static, Existing Conditions, Backcalculated Strengths
Drawn By	J.Bianchin
Scale	1:12335
Company	Bajada Geosciences, inc.
Date	4/6/2018, 11:25:07 AM
File Name	D-D'_Existing_BCStrengths.slim

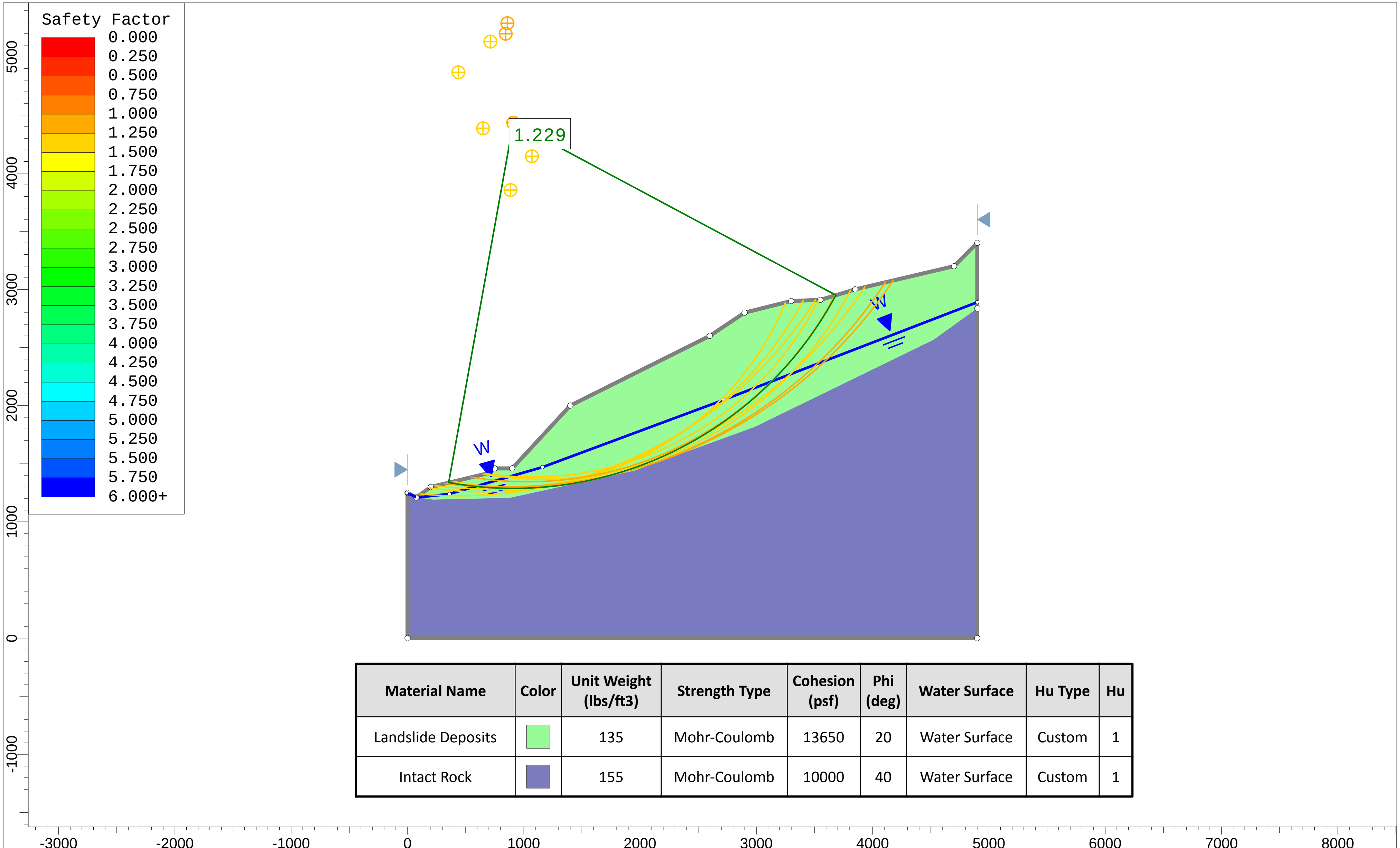


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	20000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.033

Project	Brown Quarry Review
Analysis Description	Section C-C', proposed 1.5:1 Slope, Pseusdostatic, Drained Slope Condition
Drawn By	J.Bianchin
Scale	1:11592
Company	Bajada Geosciences, Inc.
Date	4/6/2018, 9:33:53 AM
File Name	C-C'_Proposed1.5-1_BCStrengthsPS.slim

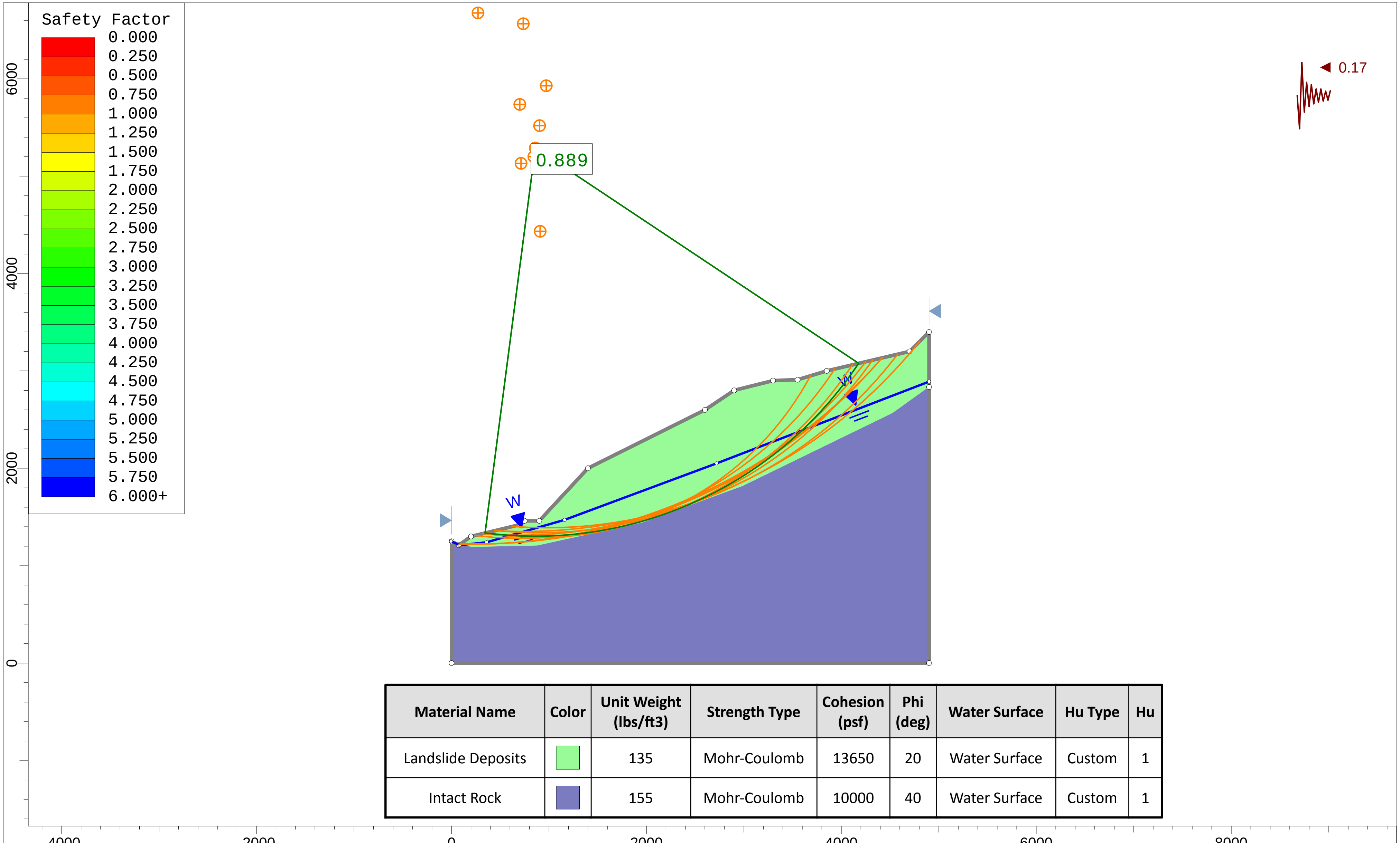


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	10000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review
Analysis Description	Section D-D', Static, Proposed 1:1 Slope, Backcalculated Strengths
Drawn By	J.Bianchin
Scale	1:13698
Company	Bajada Geosciences, inc.
Date	4/6/2018, 11:25:07 AM
File Name	D-D'_Proposed1-1_BCStrengths.slim

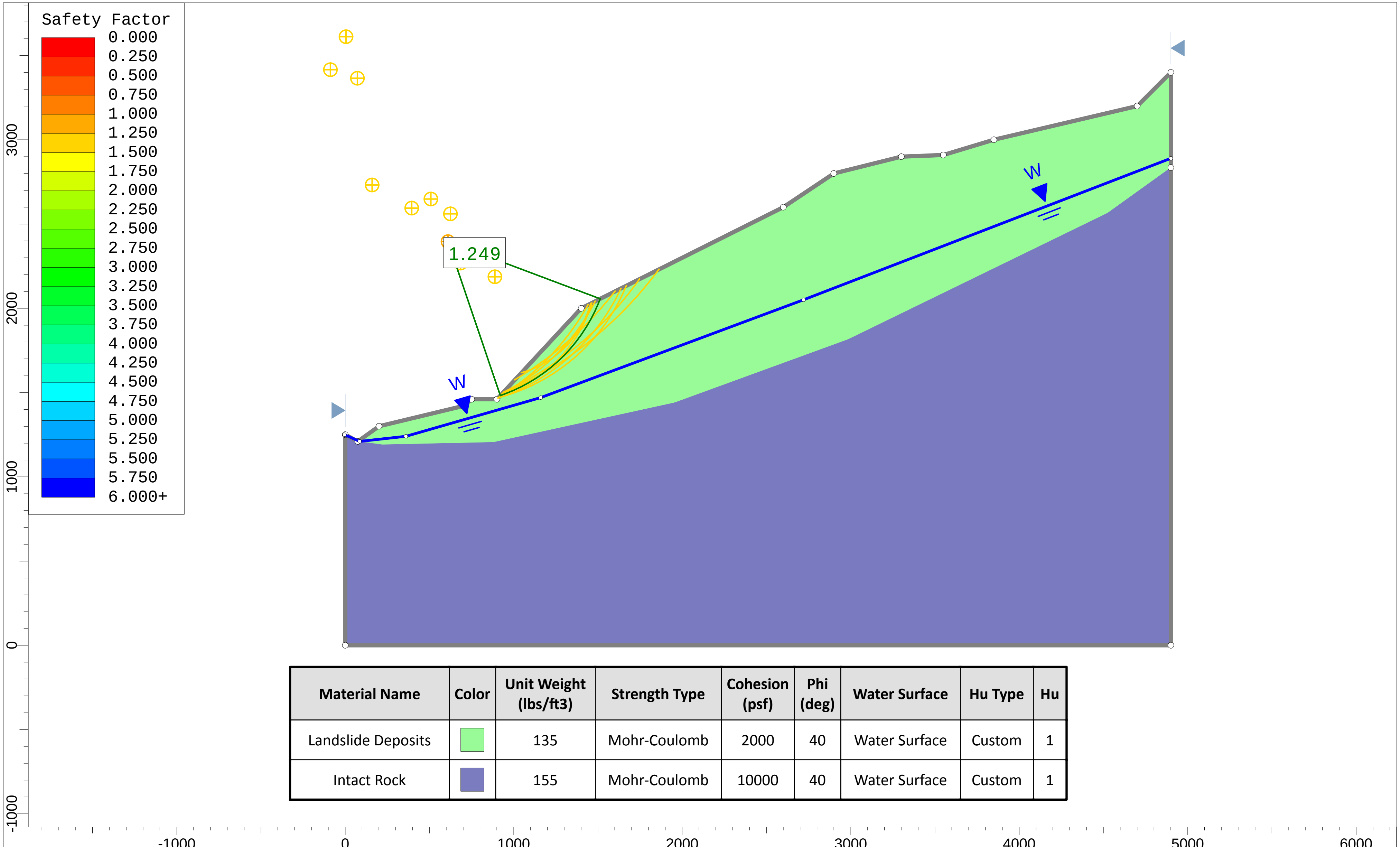


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	13650	20	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	10000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review
Analysis Description	Section D-D', Pseudostatic, Proposed 1:1 Slope, Backcalculated Strengths
Drawn By	J.Bianchin
Scale	1:16343
Company	Bajada Geosciences, inc.
Date	4/6/2018, 11:25:07 AM
File Name	D-D'_Proposed1-1_BCStrengthsPS.slim

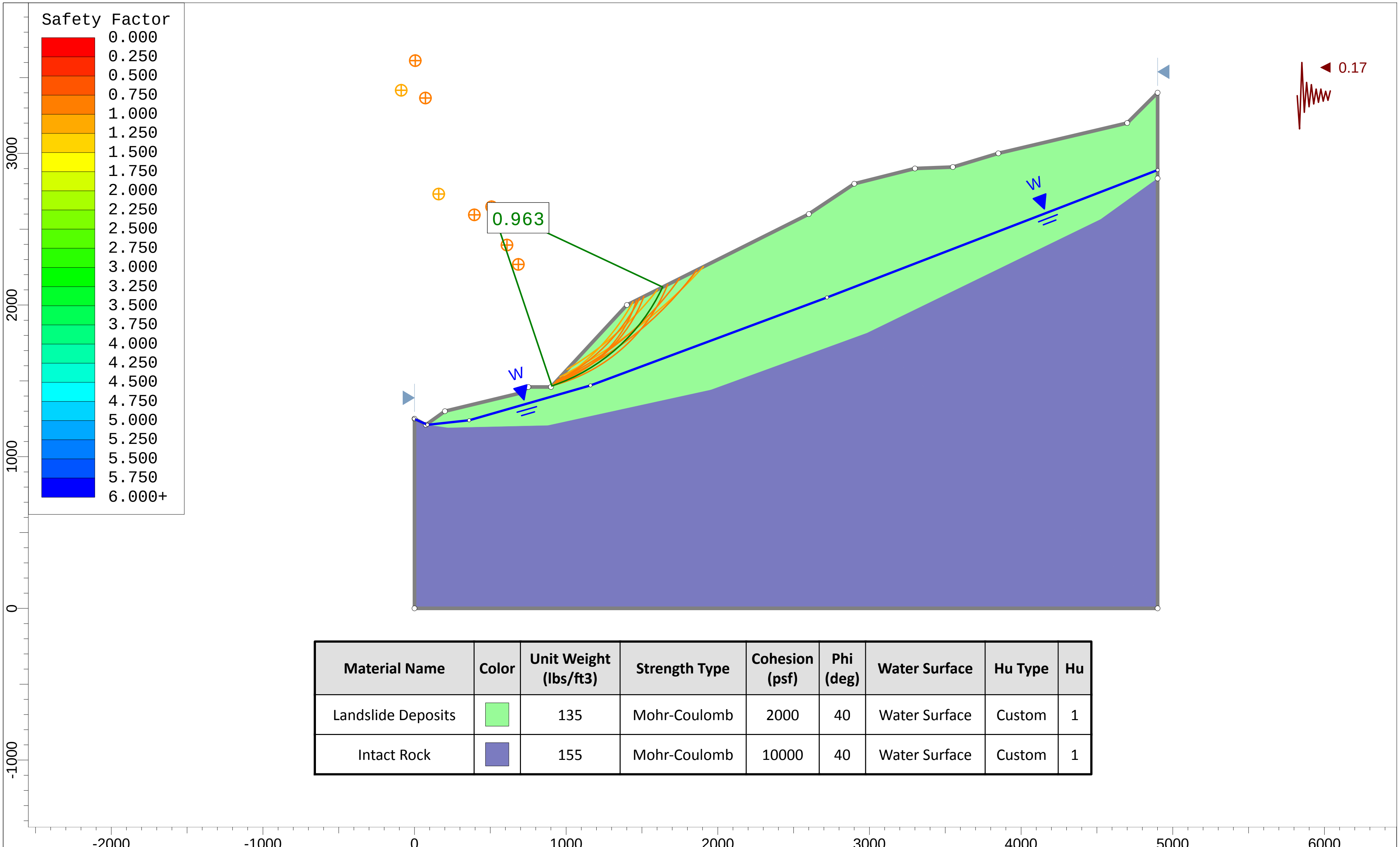


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	2000	40	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	10000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review
Analysis Description	Section D-D', Static, Proposed 1:1 Slope, C=2000 psf, phi=40
Drawn By	J.Bianchin
Scale	1:9454
Company	Bajada Geosciences, inc.
Date	4/6/2018, 11:25:07 AM
File Name	D-D'_Proposed1-1_EnchiladaStrengths.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Landslide Deposits		135	Mohr-Coulomb	2000	40	Water Surface	Custom	1
Intact Rock		155	Mohr-Coulomb	10000	40	Water Surface	Custom	1

BAJADA Geosciences, Inc.

SLIDEINTERPRET 7.030

Project	Brown Quarry Review		
Analysis Description	Section D-D', Pseudostatic, Proposed 1:1 Slope, C=2000 psf, phi=40		
Drawn By J.Bianchin	*Scale* 1:10504	*Company*	Bajada Geosciences, inc.
Date	4/6/2018, 11:25:07 AM	*File Name*	D-D'_Proposed1-1_EnchiladaStrengthsPS.slim